Proceedings of the I·R·E

JUNE 1940
VOLUME 28 NUMBER 6

Fourth Pacific Coast Convention
High-Gain Amplifier for 150 Mc.
Radio-Frequency Spark-Over in Air
Positive-Grid Characteristics
Direct-Current and Audio-Frequency Amplifier
Shunt-Excited Antenna
Ionospheric Characteristics

Institute of Radio Engineers

Pacific Coast Convention

Los Angeles, Calif., August 28, 29, and 30, 1940

SECTIONS

ATLANTA—Chairman, P. C. Bangs; Secretary, Adolph Andersen, Federal Communications Commission, 411 Federal Annex, Atlanta, Ga.

BALTIMORE—Chairman, C. A. Allert; Secretary, Alexander Whitney, 105 Shady Nook Ct., Catonsville, Md.

BOSTON—Chairman, W. L. Barrow; Secretary, P. K. McElroy, General Radio Co., 30 State St., Cambridge, Mass.

BUENOS AIRES—Chairman, A. M. Stevens; Secretary, E. E. Kapus, Bolivar 1743, Buenos Aires, Argentina.

BUFFALO-NIAGARA—Chairman, B. E. Atwood; Secretary, Leroy Fiedler, 98 West Ave., Lockport, N. Y.

CHICAGO—Chairman, E. H. Kohler; Secretary, P. C. Sandretto, United Air Lines Transport Co., 5936 S. Cicero Ave., Chicago, Ill.

CINCINNATI—Chairman, C. H. Topmiller; Secretary, W. L. Schwesinger, WSAI, Cincinnati, Ohio.

CLEVELAND—Chairman, R. L. Kline; Secretary, J. D. Woodward, WGAR, Hotel Statler, Cleveland, Ohio.

CONNECTICUT VALLEY—Chairman, R. N. Ferry; Secretary, W. M. Smith, 250 Main St., Suffield, Conn.

DETROIT—Chairman, J. D. Kraus; Secretary, Paul Frincke, WJBK, 6559 Hamilton Ave., Detroit, Mich.

EMPORIUM—Chairman, C. R. Smith; Secretary, H. L. Ratchford, Hygrade Sylvania Corp., Emporium, Pa.

INDIANAPOLIS—Chairman, Arthur Curtis; Secretary, B. V. K. French, P. R. Mallory & Co., E. Washington St., Indianapolis, Ind.

LOS ANGELES—Chairman, A. C. Packard; Secretary, J. N. A. Hawkins, 3239 Laclede Ave., Los Angeles, Calif.

MONTREAL—Chairman, A. B. Oxley; Secretary, W. A. Nichols, Canadian Broadcasting Corp., 1012 Keefer Bldg., Montreal, Que.

NEW ORLEANS—Chairman, G. H. Peirce; Secretary, D. W. Bowman, 8327 Sycamore St., New Orleans, La.

PHILADELPHIA—Chairman, C. M. Burrill; Secretary, R. L. Snyder, 103 Franklin Rd., Glassboro, N. J.

PITTSBURGH—Chairman, R. E. Stark; Secretary, M. G. Jarrett, Bell Telephone Company of Pennsylvania, Pittsburgh, Penna.

PORTLAND—Chairman, Marcus O'Day; Secretary, Earl Schoenfeld, 1627 S. E. Elliott Ave., Portland, Ore.

ROCHESTER—Chairman, H. C. Sheve; Secretary, O. L. Angevine, Jr., Stromberg-Carlson Telephone Manufacturing Co., Rochester, N. Y.

SAN FRANCISCO—Chairman, Carl Penther; Secretary, H. E. Held, 420 Market St., San Francisco, Calif.

SEATTLE—Chairman, R. M. Walker; Secretary, L. B. Cochran, University of Washington, Seattle, Wash.

TORONTO—Chairman, G. J. Irwin; Secretary, N. Potter, Canadian National Carbon Co., Ltd., 805 Davenport Rd., Toronto, Ont.

WASHINGTON—Chairman, L. C. Young; Secretary, E. M. Webster, Federal Communications Commission, Rm. 5319, New Post Office Bldg., Washington, D. C.

BOARD OF DIRECTORS

Lawrence C. F. Horle, *President*
Frederick E. Terman, *Vice President*
Melville Eastham, *Treasurer*
Harold P. Westman, *Secretary*
Austin Bailey
W. R. G. Baker
Frederick W. Cunningham
Henry C. Forbes
Alfred N. Goldsmith
Virgil M. Graham
O. B. Hanson
Raymond A. Heising
C. M. Jansky, Jr.
Frederick R. Lack
Frederick B. Llewellyn
Haraden Pratt
Browder J. Thompson
Hubert M. Turner
Arthur F. Van Dyck
Harold A. Wheeler
Lynde P. Wheeler

•

BOARD OF EDITORS

Alfred N. Goldsmith, *Chairman*
Ralph R. Batcher
Philip S. Carter
Elmer W. Engstrom
Frederick W. Grover
J. Warren Horton
Greenleaf W. Pickard
Benjamin E. Shackelford
Karl S. Van Dyke
Harold P. Westman, *ex officio*
Harold A. Wheeler
Lynde P. Wheeler
Laurens E. Whittemore
William Wilson

•

PAPERS COMMITTEE

William Wilson, *Chairman*
Frederick B. Llewellyn, *Vice Chairman*
Herman A. Affel
Edmond Bruce
Howard A. Chinn
James K. Clapp
Tunis A. M. Craven
Robert B. Dome
Paul O. Farnham
Enoch B. Ferrell
Elmer L. Hall
Dorman D. Israel
Loren F. Jones
De Loss K. Martin
Harry B. Marvin
Harry R. Mimno
Albert F. Murray
Harold O. Peterson
Ralph K. Potter
Hubert M. Turner
Dayton Ulrey
Arthur F. Van Dyck
Paul T. Weeks
William C. White
Irving Wolff

•

Helen M. Stote, *Assistant Editor*

John D. Crawford, *Advertising Manager*

Proceedings *of the* I·R·E

Published Monthly by

The Institute of Radio Engineers, Inc.

VOLUME 28 — *June, 1940* — NUMBER 6

High-Gain Amplifier for 150 Megacycles . . G. Rodwin and L. M. Klenk 257

Radio-Frequency Spark-Over in Air . . . . . P. A. Ekstrand 262

Oscillograph Method of Measuring Positive-Grid Characteristics . . . . . O. W. Livingston 267

A Direct-Current and Audio-Frequency Amplifier . . . . . L. J. Black and H. J. Scott 269

Current Distribution and Radiation Properties of a Shunt-Excited Antenna . . . . . Pierre Baudoux 271

Characteristics of the Ionosphere at Washington, D. C., April, 1940, with Predictions for July, 1940 . . . . . T. R. Gilliland, S. S. Kirby, and N. Smith 276

Institute News and Radio Notes 278
What the Institute Does for Its Members . . . . . R. A. Heising 278
Fourth Pacific Coast Convention 280
Membership 286

Books 287
"The "Radio" Handbook" . . . . . J. K. Clapp
"The Victory of Television" by Philip Kerby . . Alfred F. Murray
"Der Kondensator in der Fernmeldetechnik" by Dr.-Ing. Georg Straimer . . . . . Frederick W. Grover
"BBC Handbook 1940" . . . . . Howard A. Chinn
"Rundfunksiebshaltungen" (Radio Filters) by R. Feldkeller . . . . . R. L. Dietzold
"Der Kurzwellensender (The Short-Wave Transmitter)" by F. W. Behn and H. Monn . . . . . E. B. Ferrell
"Principles and Practice of Radio Servicing" by H. J. Hicks . . . . . Arthur Van Dyck
"Ions, Electrons and Ionizing Radiations (Seventh Edition)" by J. A. Crowther . . . . . Dayton Ulrey

Contributors 290

Entered as second-class matter October 26, 1927, at the post office at Menasha, Wisconsin, under the Act of February 28, 1925, embodied in Paragraph 4, Section 412 of the Postal Laws and Regulations. Publication office, 450 Ahnaip Street, Menasha, Wisconsin. Subscription, $10.00 per year; foreign, $11.00.

THE INSTITUTE

The Institute of Radio Engineers serves those interested in radio and allied electrical-communication fields through the presentation and publication of technical material. In 1913 the first issue of the PROCEEDINGS appeared; it has been published uninterruptedly since then. Over 1800 technical papers have been included in its pages and portray a currently written history of developments in both theory and practice.

STANDARDS

In addition to the publication of submitted papers, many thousands of man-hours have been devoted to the preparation of standards useful to engineers. These comprise the general fields of terminology, graphical and literal symbols, and methods of testing and rating apparatus. Members received a copy of each report. A list of the current issues of these reports follows·

Standards on Electroacoustics, 1938
Standards on Electronics, 1938
Standards on Radio Receivers, 1938
Standards on Radio Transmitters and Antennas, 1938.

MEETINGS

Meetings at which technical papers are presented are held in the twenty-three cities in the United States, Canada, and Argentina listed on the inside front cover of this issue. A number of special meetings are held annually and include one in Washington, D. C., in co-operation with the American Section of the International Scientific Radio Union (U.R.S.I.) in April, which is devoted to the general problems of wave propagation and measurement technique, the Rochester Fall Meeting in co-operation with the Radio Manufacturers Association in November, which is devoted chiefly to the problems of broadcast-receiver design, the Pacific Coast Convention, which is held each year during the summer months and is supervised by a joint committee of our four Pacific Coast sections, and the Annual Convention, which will be held in New York City during January.

MEMBERSHIP

Membership has grown from a few dozen in 1912 to more than five thousand. Practically every country in the world in which radio engineers may be found is represented in our membership roster. Approximately a quarter of the membership is located outside of the United States. There are several grades of membership, depending on the qualifications of the applicant. Dues range between $3.00 per year for Students and $10.00 per year for Members. PROCEEDINGS are sent to each member without further payment.

PROCEEDINGS

The contents of each paper published in the PROCEEDINGS are the responsibility of the author and are not binding on the Institute or its members. Material appearing in the PROCEEDINGS may be reprinted or abstracted in other publications on the express condition that specific reference shall be made to its original appearance in the PROCEEDINGS. Illustrations of any variety may not be reproduced, however, without specific permission from the Institute.

Papers submitted to the Institute for publication shall be regarded as no longer confidential. They will be examined by the Papers Committee and Board of Editors to determine their suitability for publication. Suggestions on the mechanical form in which manuscripts should be prepared may be obtained from the Secretary.

SUBSCRIPTIONS

Annual subscription rates for the United States of America, its possessions, and Canada, $10.00; to college and public libraries when ordering direct, $5.00. Other countries, $1.00 additional.

The Institute of Radio Engineers, Inc.
Harold P. Westman, Secretary
330 West 42nd Street
New York, N.Y.

Copyright 1940 by The Institute of Radio Engineers Inc.

High-Gain Amplifier for 150 Megacycles*

G. RODWIN†, MEMBER, I.R.E., AND L. M. KLENK†, NONMEMBER, I.R.E.

Summary—*An ultra-high-frequency amplifying system is described which operates at about 150 megacycles with an over-all gain of 114 decibels and transmitted band of over 2 megacycles. An output power of 2.5 watts is available with a signal-to-distortion ratio of 60 decibels. By a frequency-shifting modulator in the amplifier chain the input and output are made to differ by 10 megacycles. A filter-type circuit is used as the interstage coupling to give the necessary band width.*

INVESTIGATIONS of very high-frequency transmission have required development of suitable amplifying systems. The requirements for these amplifiers are that they provide substantial gain for frequency band widths on the order of those required for television, frequency modulation, multiplex telephony, etc., and that the distortion be low.

An amplifier of this type is described below. It operates at 150 megacycles, has a gain of about 115 decibels over a band 2 megacycles wide and the signal-to-distortion ratio is 60 decibels at an output of 2.5 watts.

I. General Theory and Circuits

The tubes chosen as best meeting the requirements were of two types: An acorn-type receiving tube of the pentode variety, and a medium-powered experimental tube (Western Electric type 240HH).[1] This latter tube is a push-pull pentode with an operating plate dissipation of 30 watts. The choice was determined by the desire to keep the power requirements as low as possible and yet meet the distortion limits at 2.5 watts of radio-frequency output. There were five stages using the smaller tube and a modulator and five stages using the larger tube.

Without neutralization the maximum gain per stage is limited by the plate-to-grid capacitance in the tubes.[2] In a practical amplifier the gain must be reduced well below the limit set by considerations of stability and band width. At low frequencies the gain per stage is determined by the impedance of the circuit associated with the plate of the tube. The impedance of this circuit is shunted by the input impedance of the following stage and when the frequency is high this may be important. It has been found that the impedance of a tube at ultra-high frequencies varies to some extent with input and this variation is one of the causes of distortion. In order to minimize this effect, it was necessary to make the circuit impedance low compared with the tube input impedance.

As a matter of fact the stage gain, tuning capacitance, and band width are intimately related. This can be shown very simply by the following reasoning: For a given tube of the pentode variety in which the plate-load impedance is small compared with the tube impedance, the gain per stage is given by the product of the grid-to-plate transconductance and the load impedance, i.e., gain $= G_m Z$. If the load circuit is made up of a coil and condenser in parallel, the gain may be stated as $G_m QX$, where Q is the ratio of the inductive reactance of the coil to its resistance and X is the reactance of either the inductive or capacitative branches of the circuit. Q is also a measure of the band width of the circuit and it can readily be shown that Q is definitely defined by the ratio of the operating frequency f to the frequency width of the resonance curve at points 0.707 of the maximum. If Δ is this band width, the gain per stage can be stated as

$$\text{gain} = G_m \frac{f}{\Delta} \cdot \frac{1}{2\pi f C} = G_m \cdot \frac{1}{2\pi \Delta C} .$$

Band width and capacitance then vary inversely with one another. This same derivation can be applied to filter circuits composed of a series of elements. The capacitance involved in the interstage circuit is made up of the circuit capacitance, the plate-to-ground capacitance of the amplifier tube, and the grid-to-ground capacitance of the succeeding tube. It is desirable to keep these as low as possible. Practical limitations are imposed by the relationship given above. For the acorn type of tube, a band width of 2 megacycles and a gain of 16 decibels per stage for a simple tuned circuit are obtained. If it is desired to obtain twice the band width, we must be satisfied with one half the gain. The practical usable band width is considerably less than Δ when the amplifier contains a number of stages. This reasoning shows the fallacy of assuming that greater and greater band widths are obtainable by the simple method of increasing the frequency.

In order to obtain a band width of 2 megacycles with an amplitude distortion of 0.5 decibel or less, it was necessary to use a filter circuit rather than a simple parallel coil and condenser arrangement. The circuit used was based on an arrangement consisting of a parallel circuit made up of a coil tuned by the tube capacitances and a terminating circuit of series elements. The high-frequency circuits involved are shown in Fig. 1(a). The size of the elements required in the series-terminating branch and the need for a variable element gave rise to the use of the equivalent circuit shown in Fig. 1(b). The capacitance of the condenser in series with the plate inductance was made large compared with the tube capacitances and this condenser was the variable tuning element. The amplifier was considerably easier to tune than a corresponding

* Decimal classification: R363.1. Original manuscript received by the Institute, January 16, 1940.

† Bell Telephone Laboratories, New York, N. Y.

[1] A. L. Samuel and N. E. Sowers, "A power amplifier for ultra-high frequencies," PROC. I.R.E., vol. 24, pp. 1464–1483; November, 1936.

[2] A. W. Hull, "Measurement of high-frequency amplification with shielded grid pliotrons," *Phys. Rev.*, vol. 27, pp. 439–454; April, 1926.

amplifier using the ordinary coupled circuits. The low circuit capacitances involved made it almost a necessity to tune the system by watching the indicator at the output, since it was impossible to insert a portable voltmeter on an interstage circuit without materially changing the tuning constants.

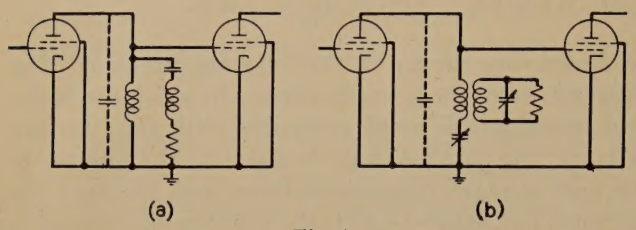


Fig. 1

Fig. 2 shows a general schematic of the complete amplifying system. Each amplifier had a load circuit of the type described. The transmission-line input was brought in through a circuit similar to the interstage circuits. The five early stages were tuned to 155 megacycles. The modulator changed the frequency by approximately 10 megacycles and the last five stages amplified the signal at approximately 145 megacycles.

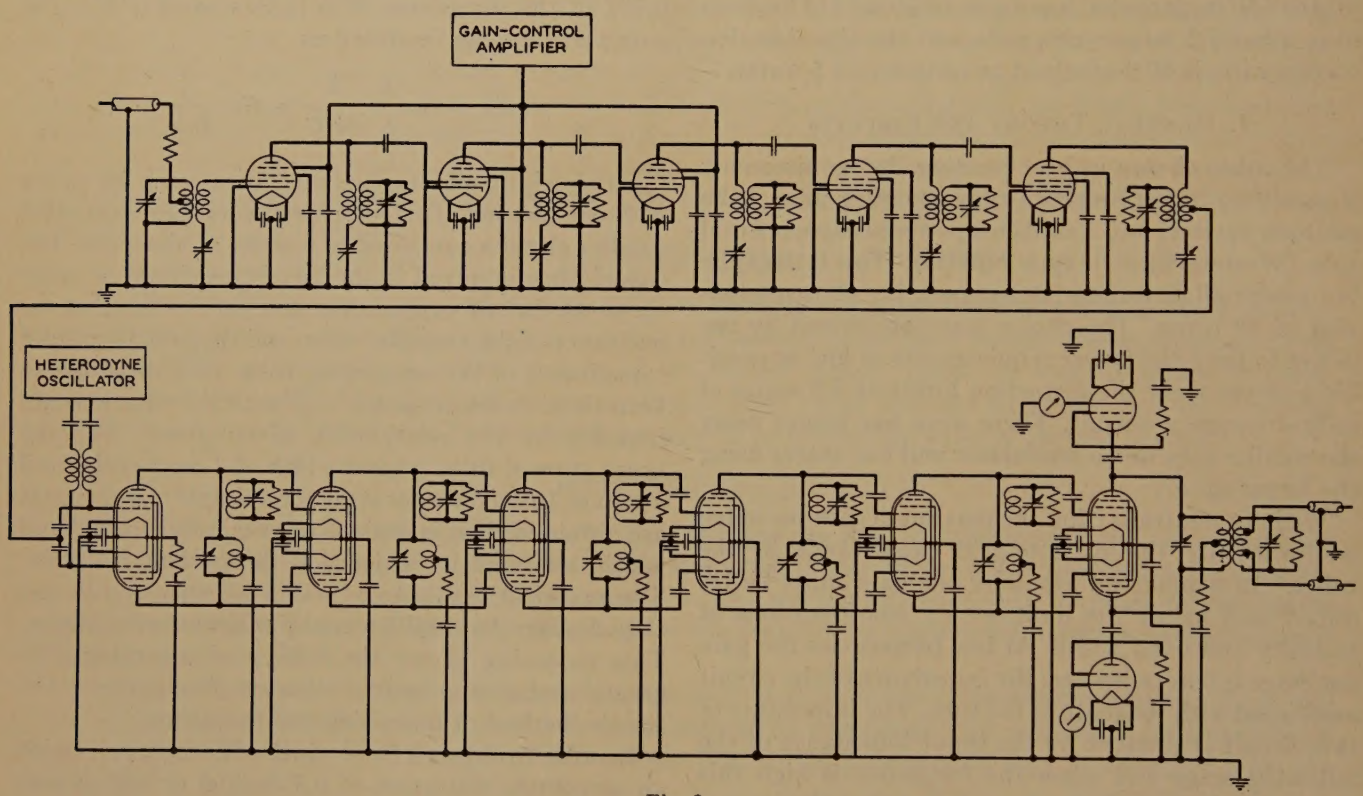


Fig. 2

The signal voltage was applied to the modulator grids in parallel and the heterodyne voltage was applied to the grids in push-pull through two grid chokes. In this manner the ultra-high-frequency circuits were kept simple. It was necessary to tap the modulator input down on the amplifier plate coil in order to maintain the band width. The heterodyne voltage, which was at a frequency of about 10 megacycles, was obtained from a crystal oscillator through an amplifier. The voltage gain through the modulator stage was found to be 1.6:1 measured from the parallel input to the push-pull output.

II. Mechanical Arrangements

The apparatus with the power supplies necessary for its operation was mounted on a seven-foot relay rack. Figs. 3 and 4 show the front and rear views. In the front view of the rack the box on the right end contains the metering apparatus, potentiometers for bias adjustment, and switches and fuses. The cover on this box was removable from the right end and a view with the cover removed is shown in Fig. 8. The central portion contained five stages of amplification at 155 megacycles, a frequency-changing modulator, and five stages of amplification at 145 megacycles. A view with the central cover removed is shown in Fig. 6. The box at the left contained a test oscillator, the heterodyne oscillator, and gain-controlling apparatus. The cover of this box was removable from the left side and a view with the cover removed is shown in Fig. 7.

The wiring and power equipment were mounted on the rear of the rack. Fig. 5 gives a view with the back covers removed.

The amplifier and modulator stages were built up as single units which were inserted one above the other. The power leads were brought out on the back end of each unit and were terminated in jacks which connected with plugs as the amplifier stage was inserted. As each stage was pushed in, the tube leads engaged

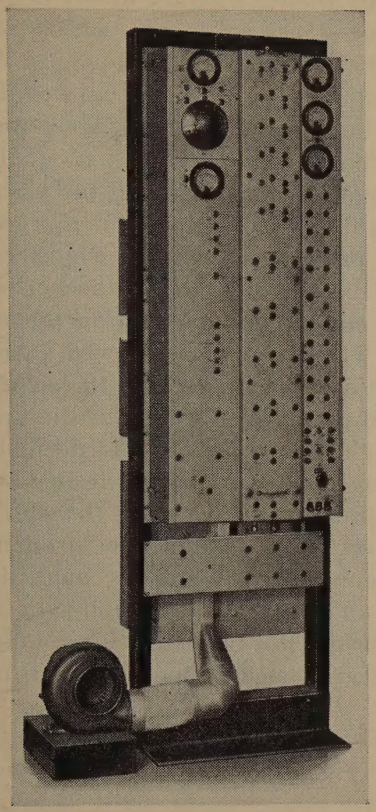


Fig. 3

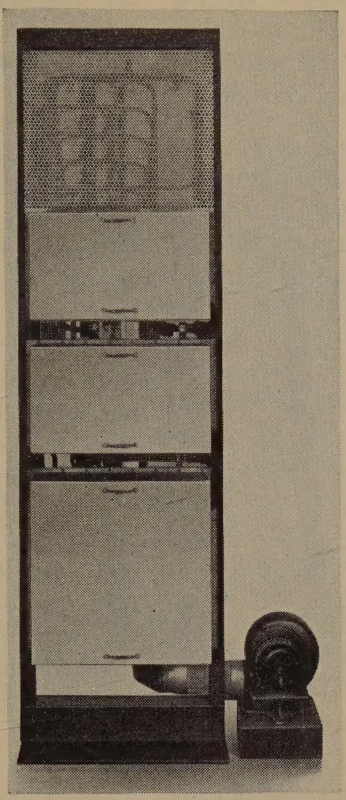


Fig. 4

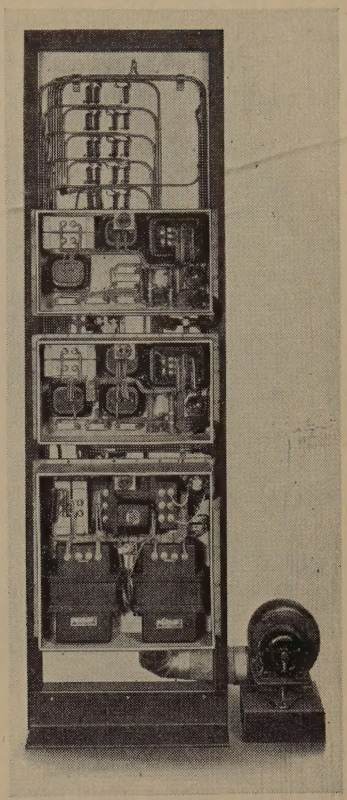


Fig. 5

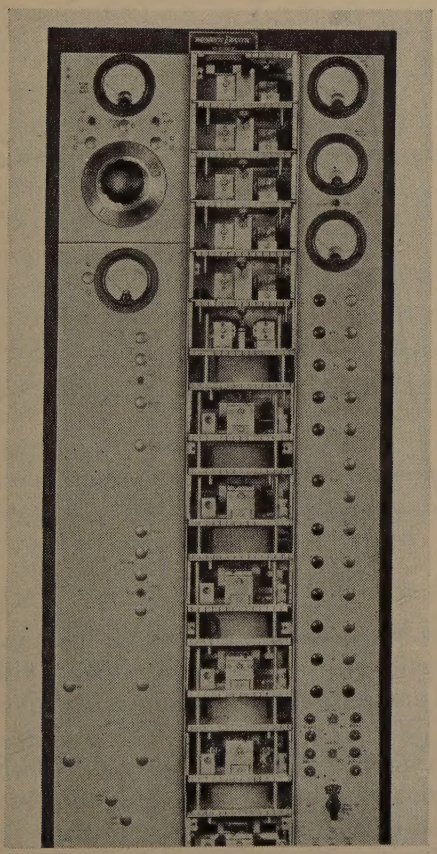


Fig. 6

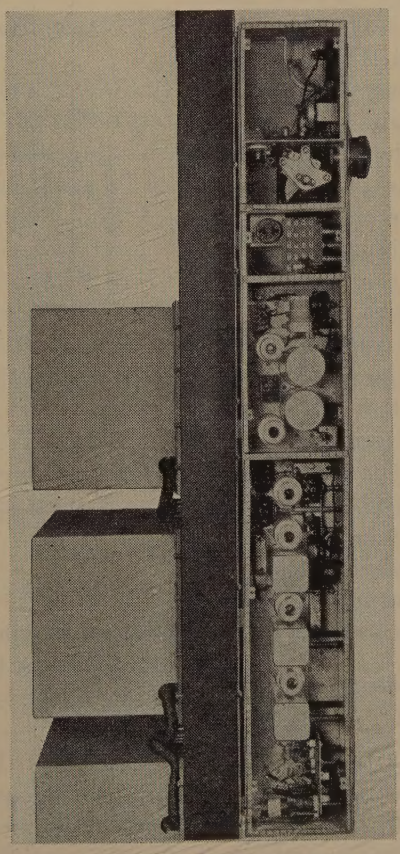


Fig. 7

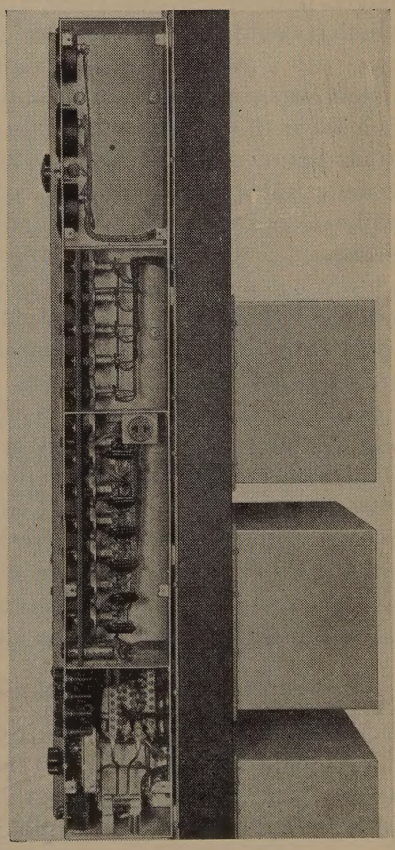


Fig. 8

clips on the preceding and following stages. In this manner, any stage could be removed without unsoldering leads. Tube changes and testing on the individual stages could then be made. Fig. 9 shows a view of one

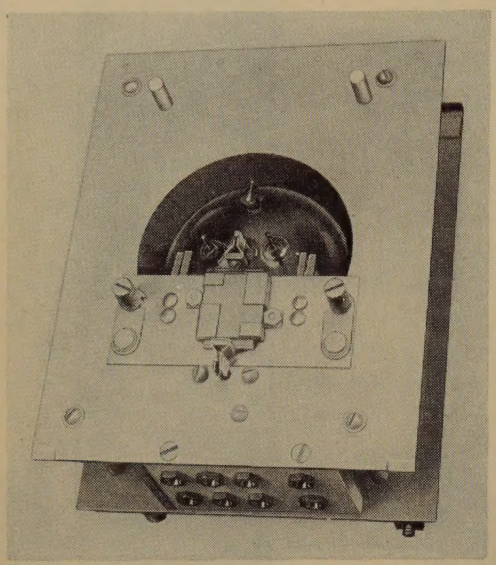


Fig. 9

of the higher-power-amplifier panels. This type of construction gave a number of advantages. Plate and grid leads were kept extremely short. Tubes could be changed quickly. In case of electrical trouble, a new stage unit could be plugged in and the stage in trouble tested with a minimum of interruption. The shielding problem was simplified, and by building up stages in this manner the input and output circuits were placed at a maximum distance from one another, thus reducing undesirable feedback. The cooling problem was readily taken care of by bringing in a stream of air at the bottom of the repeater, carrying it up along the back through a duct, and circulating it around a shell surrounding each of the larger-sized tubes.

The heterodyne oscillator and gain-controlling circuits operated at a relatively low frequency and the general construction and arrangement of parts were made similar to broadcast-receiver practice.

The filament circuits were arranged for alternating- or direct-current operation. Plate-and grid-supply voltages were obtained from three rectifiers located at the rear of the rack. Safety switches placed in series with the primary supply circuit to all transformers removed the plate and grid voltages when any cover was lifted.

III. Gain Measurements

For the measurement of gain there was built up a signal generator having a resistance attenuator, the output of which was brought out on a low-impedance transmission line correctly terminated. The termination was mounted in a plug with a blocking condenser and a flexible feeler which could be plugged directly into any stage of the amplifier preceding the modulator. The input was thus applied directly to any of the grids. A pair of high-impedance voltmeters was permanently connected to the plates of the final stages. By moving the input from stage to stage the gain of the various sections could be measured. In making over-all measurements the system was operated with about 100 peak volts of radio-frequency output across the plates of the last stage. The voltage necessary at the repeater input was thus of the order of 1 millivolt, which was readily measurable. Over-all measurements checked the sum of the stage measurements, showing the regeneration to be low. The early stages showed a gain of 12 decibels per stage and the later stages 10 decibels per stage. The over-all gain from the grid of the first stage to the plates of the last stage was 114 decibels. A field check of the over-all gain was made by connecting a half-wave antenna to the input through a transmission line and setting up a known field from an oscillator at the antenna. Taking into account the transmission-line loss and the transformation ratio in the first circuit, measurements taken in this manner checked the previous gain measurements to within 3 decibels.

Over-all band-width measurements were made. These are shown in Fig. 10. A visual setup was

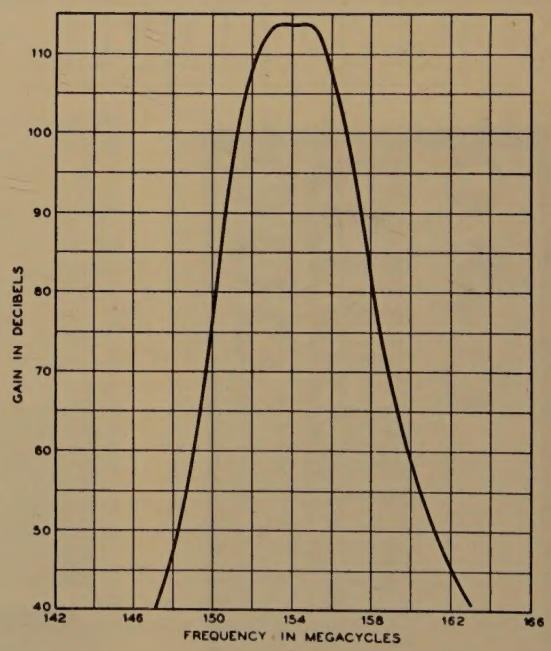


Fig. 10

used employing a sweep oscillator and cathode-ray tube to show the effect of the variation of band with tuning of the load and terminating circuits and change of coupling.

Control of the amplifier gain in the early stages was obtained by applying a negative bias to the suppressor grids. This method of control was found to vary the tuning considerably less than control of the grid or screen bias. The negative bias for automatic control was obtained from the usual type of rectifier and di-

rect-current amplifier. This rectifier obtained its input, through an amplifier, from a beat between the output and a harmonic of the heterodyne oscillator. The band width of this amplifier was about 20 kilocycles, so that in operation the system gain could be held at its proper value by a single or a narrow group of control frequencies. The effect of a variation of gain of 30 decibels on the band was to shift the band about 0.1 megacycle in absolute frequency. This is small compared with the actual band width and can be compensated for by making the band width 0.1 megaycle wider than specified. A small amount of amplitude distortion was produced by the variation in gain.

IV. Noise Measurements

With the high gain and wide transmitted band, considerable noise was noticed at the output. It was thought desirable to calculate how closely the generated noise approached that which would be expected from theoretical considerations. Nyquist[3] has shown that the noise due to thermal agitation of the charges in a conductor is given by

$$\overline{E}^2 = \frac{2}{\pi} kT \int_0^\infty R \left| G \right|^2 d\omega$$

where E^2 is the mean-square noise voltage
k is Boltzmann's constant (1.372×10^{-23} joules per degree)
T is the temperature in degrees Kelvin
R is the resistance across the input circuit
G is the voltage gain in the amplifier.

From the selectivity curve, the quantity $\int G^2 d\omega$ was obtained by breaking the area up under the curve and summing up the products of the square of the gain and the frequency width for each small sectional area. The completed noise calculation gave a result 7 decibels lower than the actual measured noise after allowance for the plate noise of the first amplifier stage.

Numerous other noise measurements were made for gains lower than the maximum. The limiting signal-to-noise ratios for medium and low gains were found to be about 67 decibels for a measured band of 5000 cycles. These last measurements were for direct current in the filament circuits. With alternating current on the filaments, the limiting signal-to-noise ratios were about 15 decibels poorer.

V. Distortion Measurements

For an amplifier in which the transmitted band is small compared with the mean frequency, the worst distortion products which fall within the band are of the third order. A measure of these can be obtained by the use of two-tone tests similar to the tests ordinarily carried out on low-frequency amplifiers. Tests of this kind were made by applying two inputs spaced by 50 to 100 kilocycles. The analyzer for picking out the various components consisted of a double-detection receiver with an intermediate-frequency band width of 3000 cycles and a calibrated attenuator in the intermediate-frequency amplifier. The receiver was tuned in turn to the fundamentals and the third-order distortion products and the attenuator set each time for constant output. The difference in attenuator settings gave the signal-to-distortion ratio. The principal distortion was found to arise in the last two stages. Ratios of the order of 60 decibels for a radio-frequency output of 2.5 watts at the plates of the last stage were obtained.

No detrimental effects were noted due to the application of negative voltages to the suppressors of the small acorn tubes. However, the presence of the simple rectifiers which were used as voltmeters at the output were found to increase the distortion considerably. It was found practicable to leave these rectifier tubes in place and open their heater circuits, in which case the signal-to-distortion ratio was not affected by their presence.

VI. Stability

One of the principal difficulties experienced with the amplifying system was the change in the over-all bandwidth characteristic on starting up from a cold condition. It was found that a warmup period of about 15 minutes was necessary to bring the selectivity characteristic back to its original form. If allowance for the warmup period is not made in the operation, an amplitude distortion of 2 to 3 decibels would have to be tolerated for this time. The effect could not be traced to a change in the circuits with temperature and could not be attributed to any measurable shift in the tube elements. A change in the space-charge distribution in the tubes would account for it.

It was found that a tube change would necessitate retuning the plate circuit. This retuning could be made rapidly with the aid of the visual selectivity indicator described previously.

This equipment has been used considerably for measurements of atmospheric noise in the ultra-high-frequency ranges. Some of the data obtained was given in a recent paper by Schafer and Goodall.[4]

[3] H. Nyquist, "Thermal agitation of electric charge in conductors," *Phys. Rev.*, vol. 32, pp. 110–113; July, 1928.

[4] J. P. Schafer and W. M. Goodall, "Peak field strength of atmospherics due to local thunderstorms at 150 megacycles," Proc. I.R.E., vol. 27, pp. 202–207; March, 1939.

Radio-Frequency Spark-Over in Air*

P. A. EKSTRAND†, ASSOCIATE, I.R.E.

Summary—*Measurements of spark-over voltage were made at 700 and 1800 kilocycles using needle points, blunt electrodes, and spheres. By impressing the voltage across a shielded capacitance of known value, then measuring the current which flows and the frequency, the voltage was calculated. Ultraviolet irradiation of the spark gap was required for consistent results. When spheres were used, the radio-frequency spark-over voltage was 17 to 20 per cent below the 60-cycle voltage. The air-density correction factor at 700 kilocycles was found to be nearly proportional to the air density. Measurements of radio-frequency spark-over voltage were made on a number of air condensers and a plate thickness of one half to one third the air gap was found to be the most satisfactory.*

Introduction

THE trend in radio transmitters is toward higher power. This means that transmitters must operate at high voltages, so there is a need for a better knowledge of the dielectric strength of air at radio frequencies.

In 1927, Reukema[1] presented curves of spark-over for 6.25-centimeter spheres for frequencies between 60 cycles and 425 kilocycles. He found that above 60 kilocycles, a single curve holds to 425 kilocycles, and that the curve was 13 per cent below the 60-cycle curve. Flooding the spheres with ultraviolet reduced the spark-over an additional 3.5 per cent. He predicted from theory that the 425-kilocycle curve will hold to at least 6 megacycles.

Recently Seward[2] made some studies of spark-over at radio frequencies. His data show a reduction of 6 to 7 per cent at 700 kilocycles from the 50-cycle value for both 0.5- and 1.4-centimeter spheres.

The present paper presents data of spark-over at 700 and 1800 kilocycles both for spheres and for needle points as well as intermediate-shaped electrodes. All of these data were taken with one electrode grounded. Measurements were made both with and without ultraviolet irradiation. The ultraviolet was generated by an electric arc using 60-cycle alternating-current power and carbon electrodes.

Voltage Generation

The circuit used to obtain the radio-frequency voltage was either the tuned-plate—tuned-grid oscillator shown in Fig. 1 or a Hartley oscillator. Shunt feed was used to remove the direct current from the plate tank circuit, so this circuit, the measuring condenser, and electrodes under test were at ground potential for direct current. The plate of the 1500-watt air-cooled tube was tapped down on the tank coil so a large step-up in voltage was obtained. The tank coil was approximately 28 inches long, 14 inches in diameter, and wound with 26 turns of $\frac{5}{8}$-inch copper tubing. The radio-frequency voltage developed across the tank coil was brought to the shielded measuring condenser, which is described in the next section, and then the lead was continued to the electrode under test. The measuring condenser shielded the test electrodes from

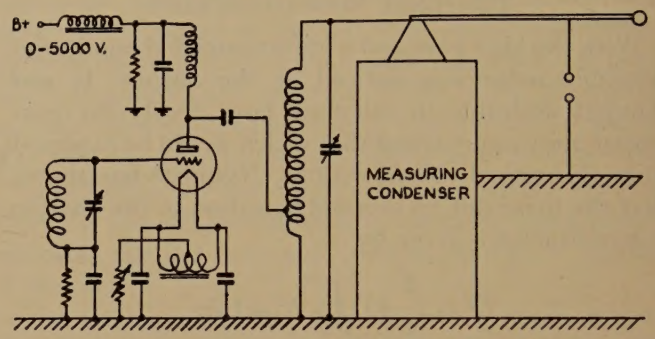


Fig. 1—Voltage generator.

the field of the tank coil. The plate voltage could only be varied in large steps, so a variable cathode resistor was used for fine voltage control. At 1800 kilocycles the measuring capacitance and stray capacitances gave sufficient tank-circuit capacitance, while at 700 kilocycles an additional compressed-gas condenser was connected across the tank coil. The circuit described was capable of generating a voltage of over 50 kilovolts peak between 700 and 1800 kilocycles.

Voltage Measurement

The voltage was measured by impressing the radio-frequency voltage across a known capacitance and measuring the current which flows. Then, knowing the capacitance, the current, and the frequency, the voltage was easily calculated by

$$E = \frac{I}{\sqrt{2}\,\pi f C}$$

where E = voltage in peak volts
I = root-mean-square current in amperes
f = frequency in cycles per second
C = effective capacitance of the measuring condenser in farads.

For accurate voltage measurements, the stray inductances and capacitances must be reduced or controlled. The stray inductances were reduced to a minimum by the use of short leads, especially from the measuring condenser to the electrodes under test. The stray capacitances were controlled by the use of the shielded measuring condenser.

* Decimal classification: R243.2. Original manuscript received by the Institute, March 21, 1940. Presented, Pacific Coast Convention, San Francisco, Calif., June 28, 1939.

† Formerly, Heintz and Kaufman, Ltd., South San Francisco, Calif. Now, Navy Yard, Mare Island, Calif.

[1] L. E. Reukema, "The relation between frequency and spark-over voltage in a sphere-gap voltmeter," *Trans. A.I.E.E.*, vol. 47, pp. 38–48; January, 1928.

[2] E. W. Seward, "The electric strength of air at high frequencies," *Jour. I.E.E.* (London), vol. 84, pp. 288–292; February, 1939.

The measuring condenser is shown in Fig. 2 in cross-sectional view. The outer box A shielded the unit and supported the high-voltage electrode B by means of the two bowl insulators D. The electrode B was approximately $3\frac{1}{2}$ inches in diameter and 15 inches long.

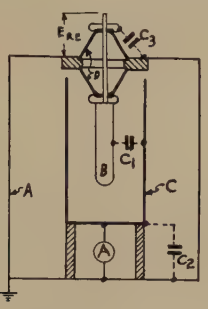


Fig. 2—Capacitance voltmeter.

The cylinder C which surrounds electrode B was supported by insulators from the bottom, and was 10 inches in diameter. The measuring ammeter was connected between cylinder C and the grounded outer case. The outer shielding box was approximately 3 feet square by 4 feet high.

As shown in Fig. 2, there are three capacitances in this arrangement, as follows:

C_1 between cylinders B and C. This is the effective measuring capacitance

C_2 between cylinder C and ground

C_3 between electrode B and ground.

The capacitance C_1 was determined by making three capacitive measurements between the electrode B and ground at the point where the voltage was applied, marked $E_{R.F.}$. For the first measurement ammeter A was removed. Then

$$C_A = C_3 + \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}.$$

Next capacitance C_1 was short-circuited

$$C_B = C_3 + C_2.$$

Then capacitance C_2 was short-circuited

$$C_C = C_3 + C_1.$$

Solving for C_1

$$C_1 = C_C - C_A + \sqrt{(C_C - C_A)(C_B - C_A)}.$$

Then C_2 and C_3 were calculated by substituting C_1 into the preceding expressions.

By making the capacitive measurements as indicated above, one side of the capacitance-measuring circuit was always grounded, and by using a capacitance substitution method the capacitance was accurately measured, either at low or at radio frequencies. For the measuring condenser used

$C_1 = 24.5$ micromicrofarads

$C_2 = 59.5$ micromicrofarads

$C_3 = 9.5$ micromicrofarads

The measuring condenser C_1 had only air dielectric, so there could be no changes in capacitance with frequency due to possible changes in the dielectric constant of an insulator with frequency. The measuring condenser was completely shielded and the measuring ammeter was shielded and at ground potential. The capacitance C_2 was high enough in impedance so there was not an appreciable shunting effect on the ammeter A at the frequencies used.

All of the radio-frequency ammeters were calibrated at 60 cycles against an ammeter of known accuracy. The frequency-correction factor of the ammeters used was applied when required.

Needle Points Spark-Over

The curves in Figs. 3 and 4 show spark-over of needle points at 700 and 1800 kilocycles for gap spacings up to 1 inch. The lower needle point was grounded and located 12 inches above a ground plane. These curves as well as the others shown were all corrected to standard air density of 760 millimeters of mercury and 25 degrees centigrade. For small changes in air density from standard conditions, it is shown later in

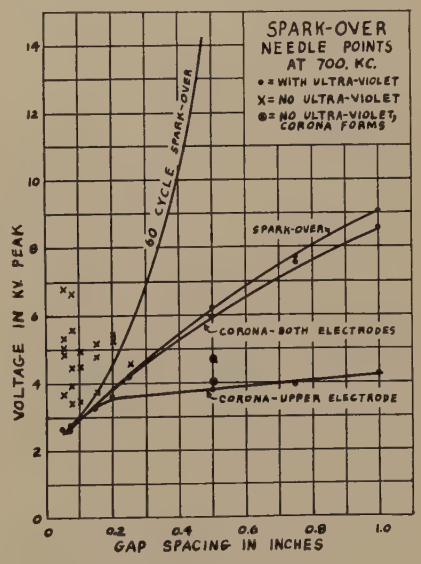


Fig. 3

the paper that the correction factor is closely proportional to air density. The crosses show the values of spark-over voltage obtained when the points were not irradiated with ultraviolet light. The points were very erratic and scattered, and at small spacings up to 0.25 inch the radio-frequency spark-over voltage often exceeded the 60-cycle value. The dots show the spark-over voltage obtained when the needle points were irradiated with ultraviolet light. As can be seen the dots fall on a smooth curve. They also gave the lowest value of spark-over voltage, and all data taken without ultraviolet irradiation fell above this curve. When the gap was over about 0.2 inch, corona occurred before spark-over. With ultraviolet irradiation, corona formed at a definite voltage, and for the upper electrode this

voltage did not increase much as the spacing was increased. Without ultraviolet, corona formed at a higher voltage, as indicated by the crosses inclosed in circles. At 700 kilocycles, after corona formed on the upper electrode the voltage was raised and then corona formed on both electrodes; then at a slightly higher voltage spark-over took place. After corona formed the spark-over voltage was definite, as the corona furnished the initial ionization. At 1800 kilocycles the spark-over voltage was not obtained above 0.5-inch spacing as the corona current caused heating and even melting of the point electrodes. At 1800 kilocycles corona formed on the upper electrode at a lower voltage than at 700 kilocycles. The curves in Figs. 3 and 4 show that needle points are not suitable for voltage measurements at radio frequencies.

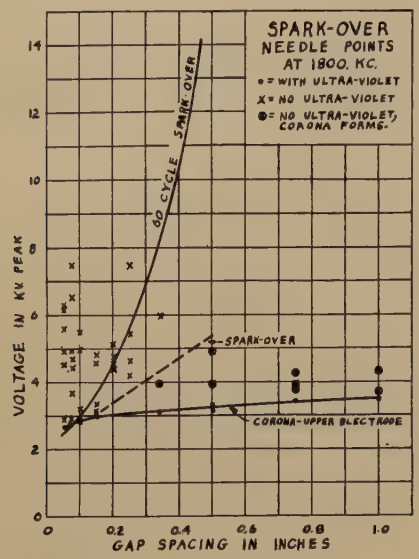


Fig. 4

Blunt Points

Measurements of spark-over voltage were made at 700 kilocycles using blunt points. The results are shown in Fig. 5. The blunt points were formed by rounding the ends of round rods into approximately the shape of a hemisphere. For the 0.05-inch rods, the spark-over voltage was somewhat scattered when no ultraviolet irradiation was used, while the smooth curve shows the spark-over voltage obtained with ultraviolet. For the 0.25-inch rods, the curve shows the spark-over voltage obtained with ultraviolet irradiation. When ultraviolet light was not used, the spark-over voltage was on the average 0.4 per cent higher. Thus as the points were made more blunt, the effect of ultraviolet light became less pronounced.

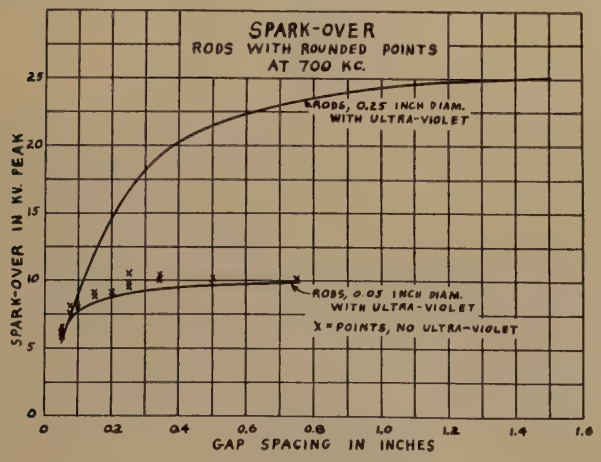


Fig. 5

Sphere Gaps

The spark-over voltage of 2.0-centimeter sphere gaps is shown in Fig. 6. The spheres were mounted as in the standard American Institute of Electrical Engineers sphere-gap arrangement with one sphere grounded,[3] except that Mycalex insulation was used to support the upper sphere and additional precautions were taken to prevent corona around the shank of the upper sphere at the support. In Fig. 6, the upper curve is the standard 60-cycle spark-over curve, while the lower curve shows the spark-over curve obtained at radio frequencies when the spheres were irradiated with ultraviolet light. A single curve held for both 700 and 1800 kilocycles. The dots show the actual measured points. The data were corrected to standard atmospheric conditions. Without ultraviolet light, it was found that the points were on the average 1 per cent higher at 700 kilocycles and 0.6 per cent higher at 1800 kilocycles. The radio-frequency spark-over curve is approximately 20 per cent below the 60-cycle curve.

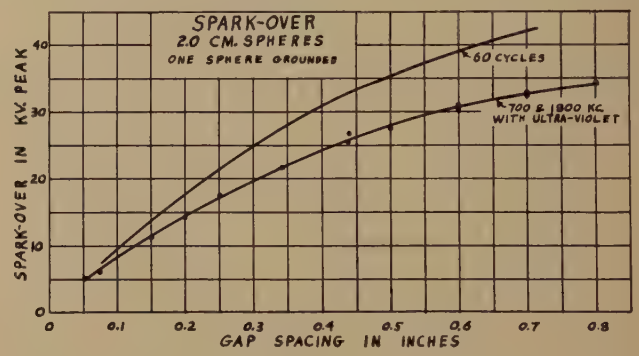


Fig. 6

Spark-over measurements were also taken for 5.08-centimeter spheres at 700 kilocycles; these results are shown in Fig. 7. The dots show the experimental points. With no ultraviolet the spark-over voltage was approximately 0.5 per cent higher than the curve shown. Without ultraviolet, the spark-over voltage was always as great or greater than with ultraviolet and the points were somewhat erratic. However, for spheres the difference was only a few per cent at most. The 700-kilocycle spark-over curve lies approximately 17 per cent below the 60-cycle curve.

[3] American Institute of Electrical Engineers Standards No. 4, on "The Measurement of Test Voltages in Dielectric Tests," May, 1928. The shank holding the sphere was less than $\frac{1}{8}$ the diameter of the sphere; the center of the lower sphere was 5 diameters from the ground plane; and the clearance to insulating members was greater than 2 diameters from the sphere.

The curves in Figs. 6 and 7 give calibrations of sphere gaps at radio frequencies up to nearly 50 kilovolts peak.

Air-Density Correction Factor

For accurate measurements it is necessary to know how spark-over voltage varies with the air density so that the proper correction factor for air density may be applied.

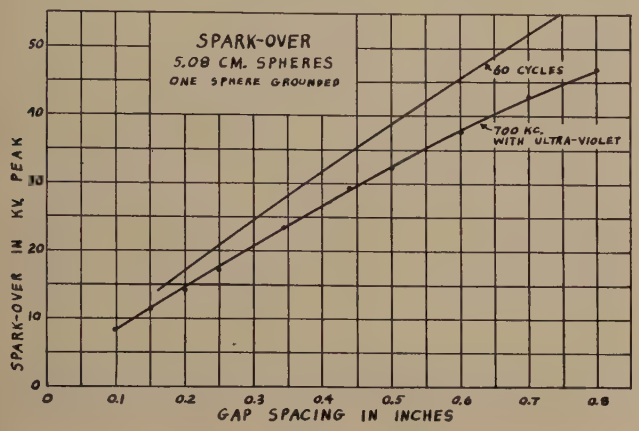


Fig. 7

Measurements were made of the air-density correction factor by placing the 2.0-centimeter spheres at 0.25-inch spacing in a compressed-gas condenser case and then making spark-over measurements at various pressures. The data are shown in Fig. 8. The crosses show the correction factor obtained when the voltage was raised rapidly, while the dots show the factor obtained when the voltage was raised slowly over a

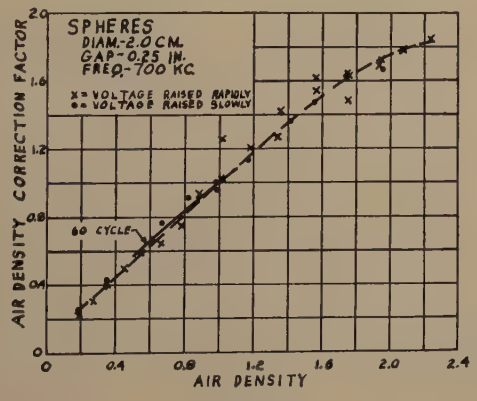


Fig. 8

period of one minute. The dots fall on a fairly smooth curve, as shown by the dashed line. The irregularity was probably due to the fact that no ultraviolet irradiation could be used due to the condenser case. The correction factor with air density was linear between 0.2 and 1.3 times standard air density. These data for 700 kilocycles may be compared with the published 60-cycle correction curve,[4] which is the solid line. The curves have practically the same slope. Therefore, for most purposes, the standard 60-cycle air-density correction factor may be used. For air densities close to unity the correction factor may be taken as equal to the air density.

This curve also shows that at high altitudes where the air density is low, the ratings of air-dielectric condensers must be reduced due to the lower dielectric strength of air at low pressures. Also, above about 1.3 times normal air density, the dielectric strength of air increases more slowly with increase in air density.

At an air density of 1.0 the spark-over voltage for the spheres was 21.4 kilovolts instead of 17.3 kilovolts as measured in the open air. This was probably due to the cylinder which inclosed the sphere gaps in this test. This metal cylinder would change the flux distribution somewhat from that of two spheres in the open air. Also, as previously pointed out, no ultraviolet irradiation could be supplied.

Comparison of Spark-Over Curves

The curves in Fig. 9 show a comparison of spark-over voltages of various electrodes with gap spacing up to 3 inches. These curves show that with small spacings the spark-over voltages are nearly the same for various types of electrodes and that the curve flattens out depending upon the diameter of the electrodes used. When the spacing is about twice the di-

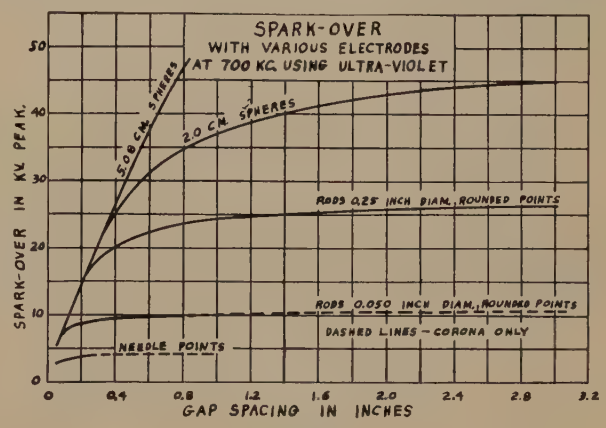


Fig. 9

ameter of the electrode, the curves have flattened out, and there is not much further increase in voltage with spacing. This indicates that air condensers should be built with thick plates. It is apparent from the curves that with well-rounded plates the plate thickness should be one half to one third the condenser spacing (air gap). This is discussed further in the next section.

Spark-Over of Air Condensers

Measurements were made of the spark-over voltage of a number of air condensers. The results are summarized in Table I. Measurements were made at 700 and 1500 kilocycles both with and without ultraviolet irradiation. The reduction of spark-over voltage with ultraviolet varied from 0 to 10 per cent, with the

[4] American Institute of Electrical Engineers Standards No. 4 on "The Measurement of Test Voltages in Dielectric Tests," May, 1928.

larger reductions at the smaller spacings. The condensers *A* and *B* with small spacings held the voltage quite well and their measured spark-over voltages were well above their ratings. Condenser *C* just exceeded its voltage rating. Condenser *D* was a condenser with thin plates and large spacing, and had a rating of 20 kilovolts peak. At 60 cycles it sparked over at 24 kilovolts peak, but at radio frequencies the spark-over voltage was low. Condenser *E* had twice the plate thickness and less than one third the plate spacing of condenser *D*, but condenser *E* would stand approximately the same radio-frequency voltage as *D*. Therefore the plates of a condenser should not be made too thin in comparison with the spacing.

TABLE I
MEASUREMENT OF SPARK-OVER OF VARIOUS AIR CONDENSERS

Condenser	A	B	C	D	E
Plate thickness, inches	0.0225	0.025	0.040	0.064	0.128
Air-gap spacing, inches	0.0245	0.080	0.192	0.719	0.218
Condition of plates	Sharp edges	Sharp edges	Rounded, Polished	Rounded, Polished	Rounded, Polished
Voltage rating in kilovolts peak	0.707	2.0	6.5	20.0	10.0
Spark-over in kilovolts peak, 60 cycles	2.72	4.2	8.4	24.	14.
Reduction with ultraviolet, 60 cycles	0	0	0	0	0
Spark-over in kilovolts peak, 700 kilocycles	2.47	3.78	7.59	14.28	13.5
Reduction with ultraviolet, 700 kilocycles	4.5%	0	1.8%	1%	0.4%
Spark-over in kilovolts peak, 1500 kilocycles	2.46	—	6.82	11.7	13.7
Reduction with ultraviolet, 1500 kilocycles	5%	—	10%	1%	0

Reduction of Spark-Over Voltage at Radio Frequencies

The reduction in spark-over voltage at radio frequency seems to be due to the fact that some ionization by collision takes place at voltages before spark-over. The negative ions have great mobility and so are removed from the field each half cycle. However, the positive ions are not swept out of the field each half cycle as they are too heavy. The positive ions remaining add to the field, and thus spark-over takes place at a lower voltage than at 60 cycles, as at power frequencies both the positive and the negative ions are swept out of the field each half cycle.[5]

Conclusions

1. A capacitive voltmeter suitable for measuring voltages up to 50 kilovolts peak was developed, and used at frequencies between 500 and 2000 kilocycles.
2. Ultraviolet irradiation is desirable when making spark-over measurements at radio frequencies to obtain consistent results.
3. When using sphere gaps, the 60-cycle voltage calibration must be reduced 20 per cent for 2-centimeter spheres and 17 per cent for 5.08-centimeter spheres for frequencies between 700 and 1800 kilocycles.
4. The air-density correction factor may be taken as proportional to the air density for small changes in air density from standard conditions.
5. For air condensers suitable for high radio-frequency voltages, a plate thickness of one half to one third the air gap should be satisfactory.

Acknowledgment

The measurements of spark-over voltage were made while I was employed at Heintz and Kaufman, Ltd., South San Francisco, Calif. I wish to thank them for the co-operation I received in the preparation of this paper.

[5] This is more completely discussed in Seward's paper. See footnote 2.

Oscillographic Method of Measuring Positive-Grid Characteristics*

O. W. LIVINGSTON†, NONMEMBER, I.R.E.

Summary—*In testing large high-vacuum tubes it is difficult to take positive-grid characteristic data using ordinary voltmeters and ammeters since the heat dissipated would destroy the tube before readings could be taken. This article describes a method of applying the desired voltages for a very short time so that overheating of the tube under test is not excessive. Readings of voltage and current are taken oscillographically.*

Introduction

CONSIDERABLE difficulty has been experienced in obtaining positive-grid characteristics of large high-vacuum triodes since the tube dissipation, while these points are being taken, is so high that the destruction of the tube is likely to take place if the power is left on sufficiently long to read a conventional meter.

To obviate this difficulty various methods have been devised.[1,2] In general, these consist of means for applying proper voltages to the tube for very short times and for recording actual voltages and currents oscillographically. In the case of very large tubes that draw high currents, the method described by Kozanowski and Mouromtseff requires a rather large anode capacitor to maintain voltage or a very low regulation supply of anode power. If the anode voltage varies somewhat, it is still possible to obtain the desired data but the amount of calculating from the oscillograms is increased greatly.

It is felt that the method to be described overcomes many of the difficulties of previous methods and provides an accurate means of obtaining the characteristic of relatively large tubes with a minimum of apparatus, "setup," and labor.

Fundamental Circuit

Fig. 1 shows a schematic diagram of the setup used for these tests. The operation is essentially as follows: The capacitors C_1 and C_2 are charged from transformers T_1 and T_2 through current-limiting resistors R_1 and R_2 and tubes VT_1 and VT_2 to a predetermined voltage. The switch S_1 is then thrown to such a position as to open the supply to the rectifier grid transformers, leaving the thyratrons VT_1 and VT_2 biased off, and to close a direct-current circuit in series with the grid transformer T_5. An impulse flows through the primary of the transformer until the series capacitor C_3 is charged. This action causes a voltage transient in the two secondaries of the transformer and throws the grids of thyratrons VT_3 and VT_4 simultaneously positive. These tubes simultaneously connect the precharged capacitors C_1 and C_2 to the grid and anode, respectively, of the tube under test. Fig. 2(a) shows the general shape of the voltage waves applied to both grid and anode. At the first instant after conduction starts, the grid and anode have essentially the same instantaneous voltage to which the capacitors have been charged.

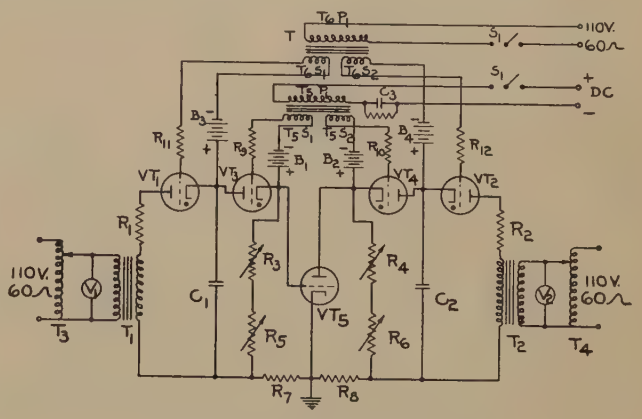


Fig. 1—Schematic diagram of circuit.

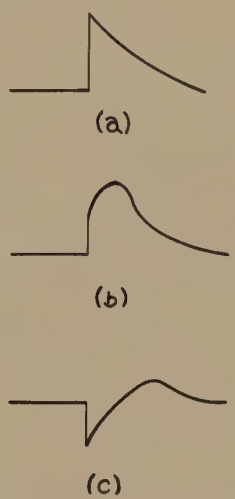


Fig. 2—Typical voltage and current curves.

If, at this same instant, the instantaneous grid and anode currents are read by means of a cathode-ray oscillograph and a suitable direct-current amplifier is connected across the shunts R_7 and R_8 for successive shots, the grid and anode currents for the particular grid and anode voltage setting may be obtained immediately.

* Decimal classification: R253. Original manuscript received by the Institute, December 23, 1939.

† Vacuum Tube Engineering Department, General Electric Company, Schenectady, N. Y.

[1] H. N. Kozanowski and I. E. Mouromtseff, "Vacuum tube characteristics in the positive grid region by an oscillographic method," PROC. I.R.E., vol. 21, pp. 1082–1096; August, 1933.

[2] R. W. Porter, "Positive grid characteristics of triodes," *Elec. Eng.*, vol. 57, pp. 693–696; December, 1938.

Operational Details

The potentiometers R_3-R_5 and R_4-R_6 permit the use of a cathode-ray oscillograph to determine the actual peak voltage applied to the tube. While it is possible in the setup used to switch the oscillograph and amplifier across either R_5, R_6, R_7, or R_8 it was found desirable first to prepare a voltage calibration curve so that by setting the alternating-current voltmeters V_1 and V_2 the desired voltage is obtained without further oscillographic measurement. Thus it is necessary to measure only the grid and anode current for any particular voltage combination.

A direct-coupled amplifier and calibration circuit is used with the oscillograph and permits an accuracy of at least plus or minus $\frac{1}{2}$ volt. Maximum voltage drop of 30 volts is permitted across the shunts. When a reading is taken sufficient negative bias is introduced in series with the grid of the amplifier so that the peak of the voltage wave just reaches a horizontal mark on the oscillograph screen. A quick-throw switch then introduces a variable direct voltage in place of the signal. This voltage is then varied until the oscillograph trace coincides with the horizontal line previously mentioned. A direct-current voltmeter connected across this voltage then reads directly the peak voltage of the applied signal. Since this voltmeter is read for each point, calibration errors in the amplifier and oscillograph are minimized.

In the case of the anode current, the wave shape is invariably similar to Fig. 2(a) and it is necessary to read only the peak. In the case of the grid current, however, the wave shape may take either this form or the form of one of the shapes shown in Fig. 2(b) or Fig. 2(c) (as the grid current becomes negative). In each of these cases the voltage at the start of the capacitor discharge should be the value measured.

When the current through the shunt causes a voltage drop which is appreciable with respect to the voltage applied to the electrode it is desirable to compensate for this in setting the capacitor voltage. This was done for the grid-voltage settings in the tests made, but it was not felt necessary to correct the anode voltage.

In the event that the leads in the circuit of the tube under test are too long, high-frequency oscillations may take place. These oscillations are immediately detected on the oscillograph by the fuzzy trace and may generally be corrected either by shortening the leads or by shunting a small capacitor from grid or anode to cathode.

Fig. 3 shows a typical set of characteristic curves obtained with this method. The actual points are plotted showing the accuracy obtained without excessive precautions.

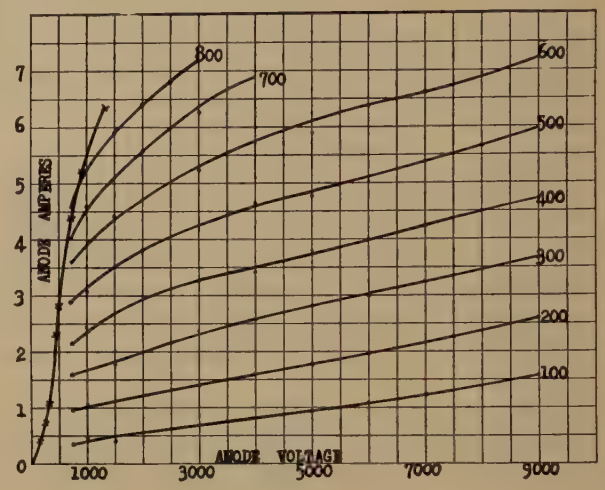


Fig. 3—GL-892 plate characteristics.

Conclusions

The method of obtaining positive-grid characteristics described has the following advantages over previous systems:

1. *Accuracy:* Since results can be plotted as soon as taken, errors are quickly noticed and points can be rechecked immediately. Oscillations can be detected at once whereas when "string" oscillographs are used these are not immediately apparent and are not generally detected until the films have been developed and computation started.

2. *Economy:* Expensive apparatus is not required. For example, both grid and anode transformers are 100 volt-ampere instrument transformers. In general, suitable cathode-ray oscillographs are inexpensive and readily used by unskilled operators whereas multielement string oscillographs are expensive and require skilled operators. The method described, while taking somewhat longer to obtain readings, does not require further calculations from oscillograms.

A Direct-Current and Audio-Frequency Amplifier*

L. J. BLACK†, ASSOCIATE, I.R.E. AND H. J. SCOTT†, ASSOCIATE, I.R.E.

Summary—*An amplifier suitable for the amplification of small direct-current and low-frequency transient potentials to a usable level is described. In this amplifier two multielement tubes are used as balanced modulators. A carrier voltage is applied in push-pull to two of the grids of these modulators. The plates of these modulator tubes, operating in parallel, are connected to a high-gain amplifier designed for the carrier frequency. Any carrier unbalance appearing in the modulator is amplified to a sufficient level in the carrier-frequency amplifier and applied to a linear detector. The amount of carrier unbalance is determined by the magnitude of the direct-current or low audio-frequency voltage applied to the control grid of one of the modulator tubes. By proper choice of operating conditions a linear relationship between impressed signal voltage and detector output voltage can be obtained. The amplifier is quite stable in its operation and is capable of amplifying signal voltages of the order of a few microvolts.*

Introduction

THE application of amplifiers outside the field of communications, such as in the measurement of mechanical stress and strain, illumination, and nerve-action currents, has greatly stimulated an interest in direct-current amplifiers. The periodicity of nerve-action potentials, which are essentially unidirectional low-frequency pulses, ranges from several seconds to several milliseconds, and the magnitude ranges from about ten microvolts to several millivolts. In the study of nerve physiology by means of these action potentials it is essential that the wave form of a pulse be faithfully reproduced. This necessitates the use of an amplifier which is capable of amplifying direct-current pulses and which is free from phase distortion at the low frequencies.

The difficulty of maintaining stable operation is familiar to everyone who has had occasion to work with high-gain direct-current amplifiers. In these amplifiers minor variations in supply voltages are amplified and appear as an output voltage of such magnitude as may completely mask the desired signal. In addition, these amplified variations of supply voltage change the direct-current operating potentials of the tubes and hence change the desired amplifier characteristics. Several experimenters[1] have suggested circuits in which the effect of minor changes in battery supply voltages is compensated for by proper choice of circuit constants. Another approach towards stability is to minimize the effect of these variations through the use of symmetrical circuits. Illustrative of this is the push-pull amplifier. For perfectly matched tubes, small variations in supply voltages have no effect upon its operation. A direct-coupled push-pull amplifier that obtains additional stability by means of a degenerative circuit has recently been described.[2] The amplifier to be described in the following paper differs in principle of operation from any of those previously mentioned.

Principle of Operation

The amplifier constitutes essentially a controlled-carrier system. A carrier voltage is applied to two tubes in a balanced bridge or modulator circuit. The signal voltage controls the degree of balance and hence the magnitude of the carrier voltage that appears in the output of the balanced modulator. In Fig. 1 is shown a

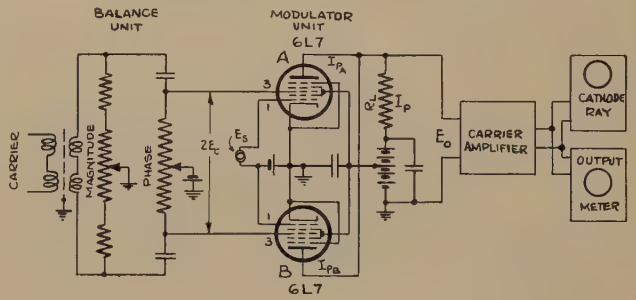


Fig. 1.

schematic diagram of such a system. The carrier is applied in push-pull to the number 3 grids of a pair of 6L7's. The plates of the two tubes are connected in parallel to the output circuit. When the proper balance adjustments are made, the carrier voltage in the output circuit is reduced to zero. In order to obtain this zero balance, it is necessary to control not only the magnitude but also the phase of the carrier voltage applied to each grid. If the impedance of the phase-balancing circuit is made high with respect to that of the magnitude-balancing circuit, the adjustments are relatively independent of each other.

If, after balance conditions are attained, a signal voltage is applied to the number 1 grid of tube A, the balance is changed and a carrier voltage appears in the output circuit. The signal voltage is indicated by E_s in Fig. 1. The magnitude of the carrier voltage appearing across the output circuit is proportional to the signal voltage.

In using the amplifier to record a signal voltage, the modulator unit is first adjusted for balanced conditions. A small amount of unbalance is then introduced by means of the variable battery shown in the number 1 grid circuit of tube B. The magnitude of this unbalancing voltage should be somewhat greater than the peak value of the signal voltage. This adjustment will

* Decimal classification: R363.2. Original manuscript received by the Institute, November 20, 1939. Presented, Pacific Coast Convention, San Francisco, Calif., June 28, 1939.

† University of California, Berkeley, California.

[1] D. B. Penick, "Direct-current amplifier circuits for use with the electrometer tube," *Rev. Sci. Inst.*, vol. 6, pp. 115–120; April, 1935. (This article contains an extended bibliography on the subject.)

[2] H. Goldberg, "A high-gain d-c amplifier for bioelectric recording," American Institute of Electrical Engineers. Technical Paper 39-124, May, 1939. Presented, American Institute of Electrical Engineers. Pacific Coast Convention, San Francisco, Calif., June 27, 1939.

give a carrier output voltage modulated approximately 100 per cent. The wave form of the carrier envelope is a replica of the signal voltage.

The relation between the carrier output voltage and the signal voltage can be expressed in terms of the tube and circuit constants as shown in the following development:

$$I_p = Ip_A + Ip_B$$
$$= \text{the carrier-frequency current in the output}$$
$$= [g_{pg3}E_C]_A - [g_{pg3}E_C]_B$$

where the subscripts A and B refer to tubes A and B, respectively.

g_{pg3} is the transconductance from grid number 3 to plate.

E_c is the carrier voltage applied to grid number 3

$$\frac{\partial I_p}{\partial E_s} = E_c \frac{\partial g_{pg3}}{\partial E_1}$$
$$= g_c \text{ the } \textit{control} \text{ conductance}$$
$$= \frac{\text{change in peak value of carrier-frequency plate current}}{\text{change in signal voltage}}.$$

(This is twice the value of the conventional conversion conductance.)

$\Delta E_0 = g_c E_s R_L$
$=$ the maximum change in the peak value of the carrier output voltage.
$E_s =$ the peak value of the signal voltage.

The quantity g_c has been termed the *control* conductance for convenience. This is equal to twice the value of the conventional conversion conductance encountered in converter operation if the signal from the beating oscillator of the converter is small. The control conductance can be readily computed from the characteristic curves for the tube and the values so obtained agree well with the measured values.

The modulated-carrier voltage E_0 can be amplified by any suitable amplifier. The envelope of the carrier can be studied directly by means of a cathode-ray oscillograph or a linear detector can be used to obtain the amplified signal voltage.

Operating Characteristics

Two sets of suitable operating conditions for the 6L7's are listed in Table I.

TABLE I

Plate voltage	Screen-grid voltage	No. 1 grid bias voltage	No. 3 grid bias voltage	Carrier voltage (peak)	Plate current per tube milliamperes	Control conductance micromhos
155	115	−6	−6	3.5	2.2	185
85	45	−3	−3	2	0.5	115

With a load resistance of 20,000 ohms in the output circuit of the modulator tubes and the set of operating conditions corresponding to a conversion conductance of 185 micromhos, a change of 1 volt direct-current signal voltage resulted in a change of 3.7 volts in the peak value of the carrier output voltage.

Since the conversion conductance is proportional to the carrier voltage it might seem that improved operation would be obtained if a larger carrier voltage, say of the order of 10 or 15 volts peak, such as is met with

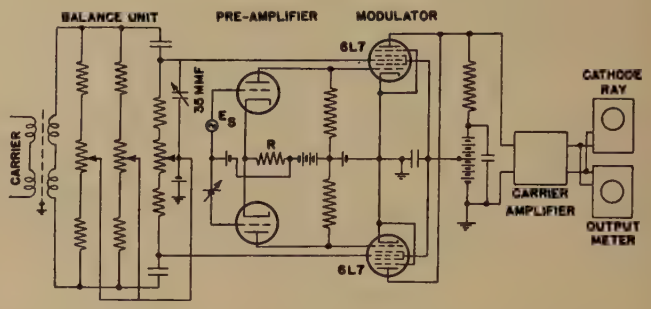


Fig. 2.

in normal converter operation, were used. With such magnitudes of carrier voltage, however, it was found that the usable sensitivity of the amplifier was not increased since the modulator became more sensitive to small direct supply voltage fluctuations.

The even harmonics of the carrier frequency generated in the modulator tubes add directly in the output circuit. Provision must, therefore, be made in the carrier amplifier so that these undesired harmonics of the carrier frequency do not appear in the final output.

For the measurement of small signals the modulator unit should be battery-operated and the carrier-frequency oscillator should apply an essentially constant voltage to the modulator tubes. The carrier amplifier, however, can be of the usual alternating-current-operated type. With the modulator battery operated the operation was quite stable. The complete amplifier system, however, did exhibit a slow undulatory drift, the magnitude of which was quite small. The maximum value of this drift measured over a three-minute time interval was less than that which would be productd by a 50 microvolt direct-current signal. The amplifier as described is quite suitable for the measurement of voltages down to the level of 50 microvolts.

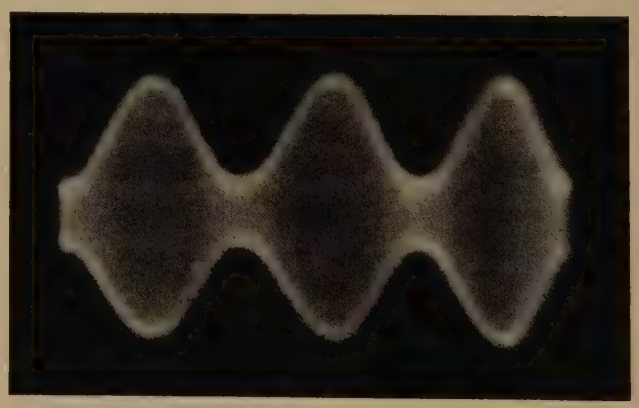


Fig. 3.

In order to measure signals of a lower level a preamplifier consisting of a single balanced stage was added. The complete amplifier is shown in Fig. 2. The stabilizing effects of resistance R are described in footnote reference 2. The addition of the preamplifier did not decrease the stability of the modulator unit but did increase the sensitivity of the amplifier as a whole. The preamplifier had a voltage gain of 20 and increased the sensivitity so that signal voltages of the order of a few microvolts could be measured.

The carrier-input circuit consisting of the balance unit and the carrier-input transformer are shown in Fig. 2. In the balance unit provision is made for fine and coarse adjustment of both magnitude and phase. The fine adjustment of phase is accomplished with the 35-micromicrofarad condenser. The carrier input is supplied through a balanced shielded transformer.

Fig. 3 is an oscillogram showing the carrier envelope resulting from the application of a 50-microvolt alternating-current signal. The noise level of the amplifier, expressed in terms of the equivalent voltage applied to the input to produce an output voltage equal to the noise voltage, is of the order of 2 microvolts. This noise voltage appears as small irregularities on the contour of the 50-microvolt signal.

The complete amplifier showed linear operation over the range for which it was designed, that is, for input signals up to 30 millivolts.

Current Distribution and Radiation Properties of a Shunt-Excited Antenna*

PIERRE BAUDOUX†, NONMEMBER, I.R.E.

Summary—*The shunt-excited antenna, first described and experimented with by Morrison and Smith,[1] was found to have a current distribution similar to that of the classical insulated-base antenna, except near the grounded base. Therefore, the shunt-excited antenna should have nearly the same radiation properties as an insulated-base antenna having the same length and radiating at the same wavelength.*

The present work is an attempt to investigate theoretically whether and to what extent these predictions are justified. The current distribution is, therefore, calculated according to the ordinary simplified line theory.

The radiation pattern is thereafter derived and a formula for the radiation resistance is found. The radiation resistance is calculated numerically as a function of the ratio "antenna-length/wavelength." It seems to be in many cases very different for a shunt-excited antenna than for an insulated-base antenna.

I. Potential and Current Distribution Along a Shunt-Excited Antenna

LET us consider the antenna as a nonresistive wire, excited by an inclined conductor (Fig. 1). The latter can be neglected, since it has but a small influence on the current distribution and, consequently, on the radiation pattern.

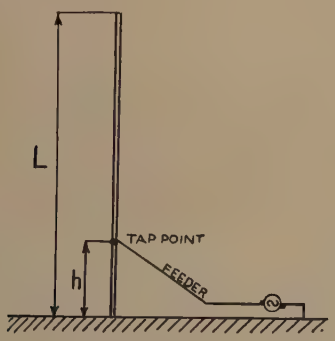


Fig. 1—Schematic disposition of a shunt-excited antenna.

The antenna being grounded at its base, the potential at its base point will be null. The potential amplitude at the tap point is fixed by the source and the value of this amplitude is another limiting condition of our problem.

Finally, a third condition is given at the top point, where the current is zero under all conditions.

Notations used

L = antenna height
h = height of tap point above earth plane
z = height of an arbitrary section above earth plane
l_0 = self-inductance per unit length of wire
c_0 = capacitance per unit length of wire
ω = angular frequency of radiated wave
a = portion of antenna above tap point
b = portion of antenna below tap point
V = potential amplitude at an arbitrary point
I = current amplitude at an arbitrary point

$$c = 1/\sqrt{l_0 c_0}$$ propagation velocity in the wire

$$\psi = \frac{\omega L}{c}$$ angular height of antenna

$$\chi = \frac{\omega h}{c}$$ angular height of tap point

Assuming a sine-wave distribution of potential and current, let us write

$$V_a = A \sin \frac{\omega z}{c} + B \cos \frac{\omega z}{c} \text{ for } a \text{ region.}$$

$$V_b = C \sin \frac{\omega z}{c} + D \cos \frac{\omega z}{c} \text{ for } b \text{ region.}$$

Introducing the relation $-dV/dz = j\omega l_0 I$ we get, for the a region, $\cdots I_a = j/l_0 c(A \cos \omega z/c - B \sin \omega z/c)$ and for the b region, $\cdots I_b = j/l_0 c(C \cos \omega z/c - D \sin \omega z/c)$.

* Decimal classification: R120. Original manuscript received by the Institute, January 29, 1940.

† Institute of Telecommunications, University of Brussels, Brussels, Belgium.

[1] J. F. Morrison and P. H. Smith, "The shunt-excited antenna," PROC. I.R.E., vol. 25, pp. 673–696; June, 1937.

In order to determine the constants, we have

(1) top section: $z=L \cdots I_a(L)=0$

(2) base section: $z=0 \cdots V_b(0)=0$

(3) tap point: $z=h \cdots V_a(h)=V_b(h)=V_h$.

Introducing these conditions, we find the potential distribution

(a region) $$V_a/V_h = \frac{\cos\psi(1-z/L)}{\cos(\psi-\chi)} \qquad (1)$$

(b region) $$V_b/V_h = \frac{\sin\psi(1-z/L)}{\sin\chi}. \qquad (2)$$

Going further

$$\frac{jV_h}{l_0 c\cos(\psi-\chi)} = I_a^m.$$

We have for the current distribution

(a region) $$\frac{I_a}{I_a^m} = \sin\psi(1-z/L) \qquad (3)$$

(b region) $$\frac{I_b}{I_a^m} = \frac{\cos(\psi-\chi)}{\sin\chi}\cos\psi z/L. \qquad (4)$$

It should be noted that in the a region the current distribution does *not* depend upon the height h of the tap point (or from its angular height χ).

Further, in the same portion of antenna, the distribution is exactly the same as in an insulated-base antenna.

However, in the usually much shorter portion b, between earth and tap point, we find a quite different distribution than that of a classical antenna.

It should be noted also that for a *quarter-wave* antenna, the distribution is exactly the same as in the case of an insulated-base antenna, along the whole length the feeding height h having no more influence.

Base current. Making $z=0$ in (4), we get

$$\frac{I_b^0}{I_a^m} = \frac{\cos(\psi-\chi)}{\sin\chi}.$$

Excitation current. Making $z=h$ in (3) and (4),

$$\frac{I_a^h}{I_a^m} = \sin(\psi-\chi)$$

$$\frac{I_b^h}{I_a^m} = \cos(\psi-\chi)\operatorname{cotan}\chi.$$

The difference between these two values is obviously equal to the current in the feeder. The excitation current is thus

$$I_f = I_a^h - I_b^h$$

hence $$\frac{I_f}{I_a^m} = -\frac{\cos\psi}{\sin\chi}.$$

II. Impedance at the Tap Point of a Shunt-Excited Antenna

The impedance at the tap point is

$$Z = \frac{V_h}{I_f} = -\frac{V_h}{I_a^m}\cdot\frac{\sin\chi}{\cos\psi}$$

or $$Z = j\sqrt{\frac{l_0}{c_0}}\,\frac{\sin\chi\cos(\psi-\chi)}{\cos\psi}.$$

Writing

$$Z_0 = \sqrt{\frac{l_0}{c_0}}\ \text{(characteristic impedance of wire)}$$

we may write also

$$\frac{Z}{Z_0} = j\frac{\sin\chi\cos(\psi-\chi)}{\cos\psi}.$$

Fig. 2 shows the variation of the ratio Z/Z_0 as a function of the angular height of antenna $\psi=\omega L/c$

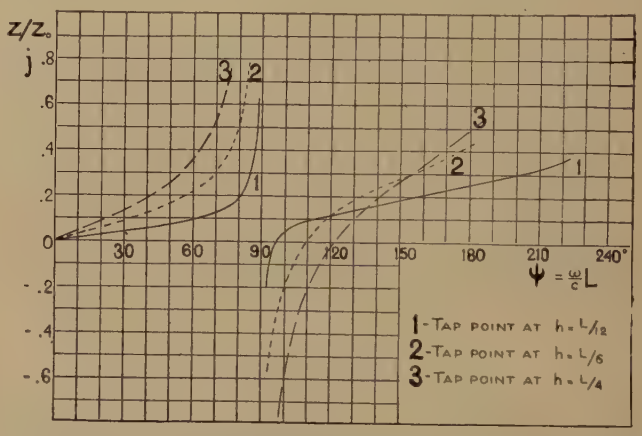


Fig. 2—Ratio $\frac{\text{impedance at tap point}}{\text{characteristic impedance of wire}}$ as a function of $\psi=\omega L/c$ (angular height of antenna).

for three values of the feeding height, namely, $h=L/12$ (or $\chi=\psi/12$), $h=L/6$ ($\chi=\psi/6$), and $h=L/4$ ($\chi=\psi/4$).

III. Radiation Pattern of a Shunt-Excited Antenna

The vertical component of the radiated electric field, taken at the point $P(R, \theta)$ of polar co-ordinates where

R = distance of P from the antenna base and

θ = angle of R above a horizontal plane,

is noted by $H(R, \theta)$.

The ratio

$$h = \frac{H(R,\theta)}{H(R,0)}$$

is a function of θ only.

If we plot h versus θ in a system of polar co-ordinates (h, θ) we obtain the vertical radiation pattern of the antenna.

It is well known that if the current distribution is

given by the arbitrary function $f(z/L)$ the radiation pattern h is then furnished by the expression[2,3,4]

$$h = \frac{\int_0^1 f(\zeta) \cos(\psi\zeta \sin\theta) d\zeta}{\int_0^1 f(\zeta) d\zeta} \cos\theta$$

where $\zeta = z/L$.

Here, with the current distribution derived above, we have (see Appendix I)

$$h = \frac{\cos(\psi \sin\theta) - \dfrac{\cos\psi}{\sin\chi} \sin\theta \sin(\chi \sin\theta)}{\cos\theta}.$$

[2] H. E. Gihring and G. H. Brown, "General considerations of tower antennas for broadcast use," PROC. I.R.E., vol. 23, p. 342; April, 1935.
[3] P. O. Pedersen, "Radiation from a vertical antenna over flat perfectly conducting earth," Copenhagen, 1935.
[4] P. Baudoux, "L'Antenne rayonnante," Paris, p. 170, 1938.

Figs. 3 to 8 show the current distributions and radiation patterns of a shunt-excited antenna for several values of ψ, i.e., for several values of the ratio L/λ (λ = wavelength).

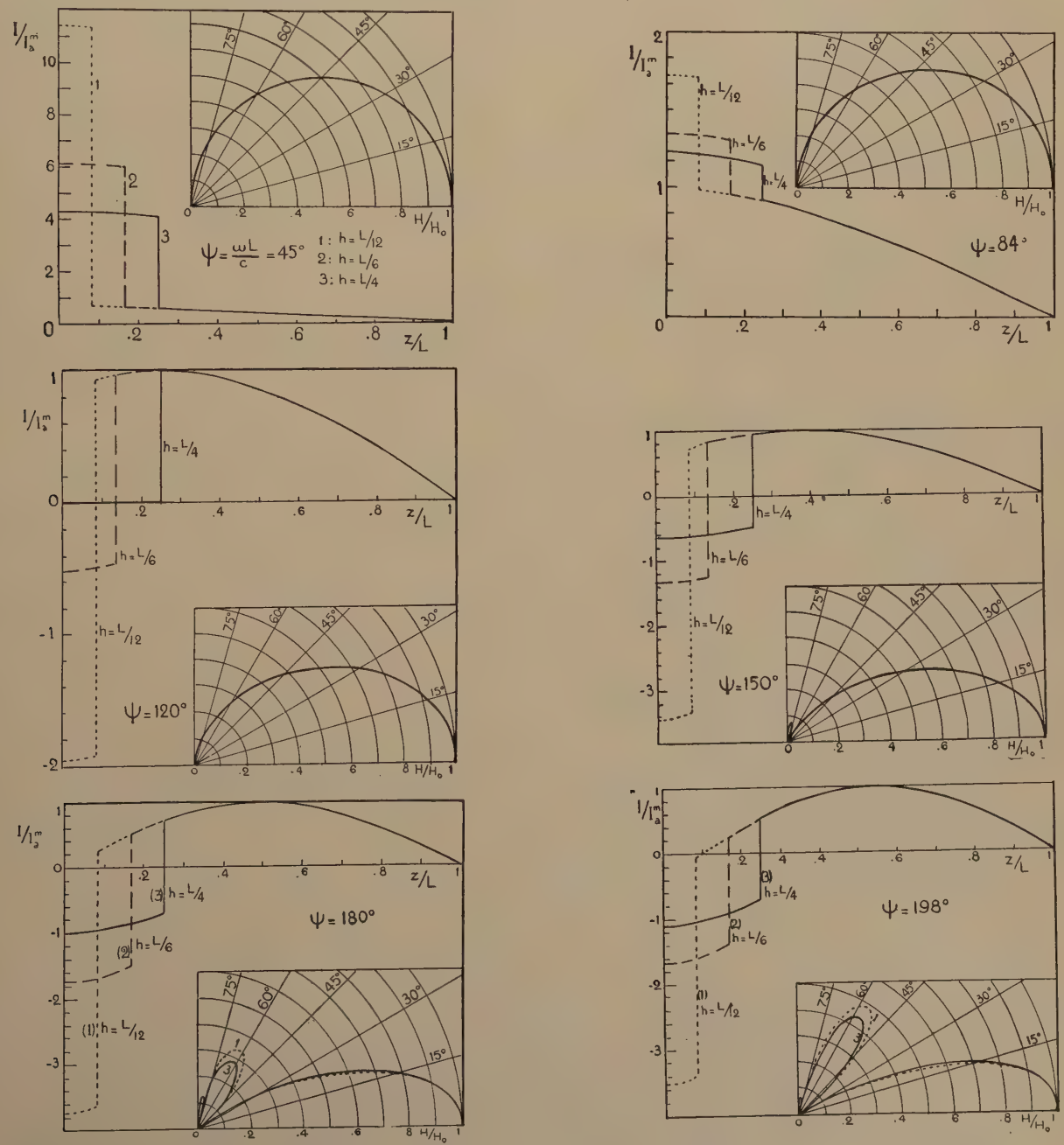
IV. Radiation Resistance of a Shunt-Excited Antenna

When the radiation diagram is known, the radiation resistance can be calculated as follows:

Let us take

$$Y_0 = \int_0^1 f(\zeta) d\zeta$$

$$\Phi = \int_0^{\pi/2} h^2(\theta) \cos\theta d\theta.$$



Figs. 3–8—Current distribution and radiation patterns of a shunt-excited antenna for several values of ψ.

Then the radiation resistance is given by

$$R_r = 60\psi^2 Y_0^2 \Phi \text{ ohms.}$$

Here we have $Y_0 = 1/\psi$

thus $$R_r = 60\,\Phi \text{ ohms}$$

and the function Φ has to be calculated. This derivation, which is rather complicated, will be found in Appendix II. The result is

$$\Phi = M(\psi) + \frac{\cos\psi}{2\sin\chi}\left\{ N(\chi)\frac{\cos\psi}{2\sin\chi} + \cos(\psi+\chi)\mathrm{Si2}(\psi+\chi) - \cos(\psi-\chi)\mathrm{Si2}(\psi-\chi) + \sin(\psi+\chi)G2(\psi+\chi) - \sin(\psi-\chi)G2(\psi-\chi)\right\}$$

where

$$M(\psi) = \frac{\sin 2\psi}{4}\mathrm{Si}4\psi - \frac{\cos 2\psi}{4}G4\psi$$

$$N(\chi) = \cos 2\chi \cdot G4\chi - \sin 2\chi \mathrm{Si}4\chi - 2\left(1 - \frac{\sin 2\chi}{2\chi}\right)$$

$$G(x) = C + \log_n x - \mathrm{Ci}x$$

the symbols Si and Ci representing, as usual, the sine integral and the cosine integral.

The constant C, called Euler's constant, has the value

$$C = 0.5772157 \cdots.$$

The functions Si and Ci have been tabulated by Jahnke and Emde, and more accurately, by Tani.[5]

TABLE I

NUMERIC VALUES OF THE RADIATION RESISTANCE

Angular height of antenna	ratio $\left(\frac{\text{antenna height}}{\text{wavelength}}\right)$	Radiation resistance in ohms		
		$h=L/12$	$h=L/6$	$h=L/4$
30°	1/12 =0.0825	42.81	35.88	40.44
36°	1/10 =0.1000	40.80	39.84	39.66
45°	1/8 =0.1250	41.10	40.08	39.84
60°	1/6 =0.1667	38.10	40.02	39.36
72°	1/5 =0.2000	38.46	38.46	38.34
90°	1/4 =0.2500	36.48	36.48	36.48
120°	1/3 =0.3333	31.02	31.14	30.30
135°	3/8 =0.3750	27.54	27.60	
150°	5/12 =0.4167	25.56	24.18	
180°	1/2 =0.5000	19.62	19.50	
192°	8/15 =0.5325	18.00	19.66	

The radiation resistance calculated above refers to the current at the current loop (i.e., I_a^m).

In any other section the radiation resistance can be found immediately by multiplying the figure stated before by

$$(I_a^m/I_z)^2$$

I_z being the current in the arbitrary section.

Referring to the current at the base point

$$R_r^0 = R_r \cdot \frac{\sin^2\chi}{\cos^2(\psi-\chi)}.$$

[5] K.Tani, "Tables of si(x) and ci(x) for the range $x=0$ to $x=50$," Tokyo, 1931.

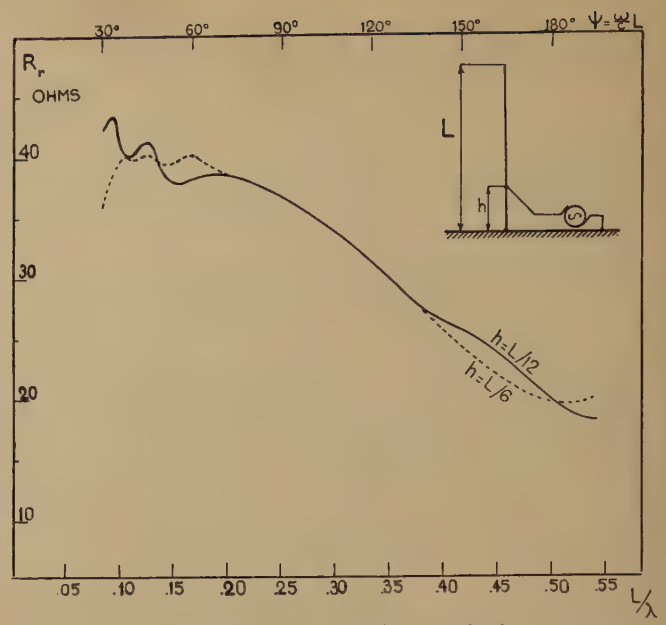


Fig. 9—Radiation resistance of the shunt-excited antenna as a function of the ratio $\frac{\text{antenna height}}{\text{wavelength}}$.

Referring to the current in the feeder

$$R_r^f = R_r \cdot \frac{\sin^2\chi}{\cos^2\psi}.$$

In most cases, the radiation resistance appears to be very different from that of the corresponding insulated-base antenna.

APPENDIX I

Derivation of Radiation Pattern

We have to derive the function

$$h = \frac{Y(\theta)}{Y_0}\cos\theta$$

where $$Y(\theta) = \int_0^1 f(\zeta)\cos(\psi\zeta\sin\theta)d\zeta$$

$$Y_0 = \int_0^1 f(\zeta)d\zeta.$$

In our case, the current-distribution function $f(\zeta)$ is

from $z = 0$ to $z = h$: $$\frac{I_b}{I_a^m} = \frac{\cos(\psi-\chi)}{\sin\chi}\cos\psi\zeta$$

from $z = h$ to $z = L$: $$\frac{I_a}{I_a^m} = \sin\psi(1-\zeta).$$

We have thus

$$Y(\theta) = \int_0^{\zeta_1}\frac{I_b}{I_a^m}\cos(\psi\zeta\sin\theta)d\zeta + \int_{\zeta_1}^1\frac{I_a}{I_a^m}\cos(\psi\zeta\sin\theta)d\zeta = Y_b + Y_a.$$

The integrals are easy to evaluate

$$Y_b = \frac{\cos(\psi-\chi)}{\sin\chi}\int_0^{\zeta_1}\cos\psi\zeta\cos(\psi\zeta\sin\theta)d\zeta \quad (\zeta_1 = h/L)$$

$$= \frac{\cos(\psi-\chi)}{\sin\chi} \cdot \frac{\sin\psi\cos(\chi\sin\theta) - \sin\theta\cos\chi\sin(\chi\sin\theta)}{\psi\cos^2\theta}$$

$$Y_a = \int_{\zeta_1}^{1}\sin\psi(1-\zeta)\cos(\psi\zeta\sin\theta)d\zeta$$

$$= \frac{\cos(\psi\sin\theta) + \sin\theta\sin(\psi-\chi)\sin(\chi\sin\theta) - \cos(\psi-\chi)\cos(\chi\sin\theta)}{\psi\cos^2\theta}.$$

Making the sum of Y_b and Y_a, we obtain

$$Y = \frac{\cos(\psi\sin\theta) - \frac{\cos\psi}{\sin\chi}\sin\theta\sin(\chi\sin\theta)}{\psi\cos^2\theta}.$$

But, making $\theta=0$, we have

$$Y_0 = \frac{1}{\psi}$$

thus

$$\frac{h\cos(\psi\sin\theta) - \frac{\cos\psi}{\sin\chi}\sin\theta\sin(\chi\sin\theta)}{\cos\theta}$$

Appendix II

Derivation of Function Φ

The function we have to derive is given by

$$\Phi = \int_0^{\pi/2} h^2\cos\theta d\theta$$

or

$$\Phi = \int_0^{\pi/2} \frac{\left[\cos(\psi\sin\theta) - \frac{\cos\psi}{\sin\chi}\sin\theta\sin(\psi\sin\theta)\right]^2}{\cos\theta} d\theta.$$

Putting

$$\sin\theta = v-1$$

we get

$$\Phi = \frac{1}{2}\int_0^2 \left[\cos\psi(v-1) - \frac{\cos\psi}{\sin\chi}(v-1)\sin\chi(v-1)\right]^2\frac{dv}{v}.$$

Developing, we obtain

$$= -\frac{\cos 2\psi}{4}\int_0^2\frac{1-\cos 2\psi v}{v}dv + \frac{\sin 2\psi}{4}\int_0^2\frac{\sin 2\psi v}{v}dv + \frac{a^2}{4}\cos 2\chi\int_0^2\frac{1-\cos 2\chi v}{v}dv - \frac{a^2}{4}\sin 2\chi\int_0^2\frac{\sin 2\chi v}{v}dv + \frac{a}{2}\cos(\psi+\chi)\int_0^2\frac{\sin(\psi+\chi)v}{v}dv - \frac{a}{2}\cos(\psi-\chi)\int_0^2\frac{\sin(\psi-\chi)v}{v}dv - \frac{a}{2}\sin(\psi-\chi)\int_0^2\frac{1-\cos(\psi-\chi)}{v}dv + \frac{a}{2}\sin(\psi+\chi)\int_0^2\frac{1-\cos(\psi+\chi)v}{v}dv + \frac{a^2}{4}\cos 2\chi\int_0^2 v\cos 2\chi v dv + \frac{a^2}{4}\sin 2\chi\int_0^2 v\sin 2\chi v dv - \frac{a^2}{2}$$

where $$a = \frac{\cos\psi}{\sin\chi}.$$

These integrations provide the results stated in the text.

Acknowledgment

The author wishes to thank Prof. E. Divoire, director of the Radio-Laboratory, Institute of Telecommunications, Brussels University, and Mr. Raymond Braillard, director of the "Centre de Contrôle" of the Union Internationale de Radio Diffusion, for the interest they took in this work and for their helpful encouragement.

Characteristics of the Ionosphere at Washington, D.C., April, 1940, with Predictions for July, 1940*

T. R. GILLILAND†, ASSOCIATE, I.R.E., S. S. KIRBY†, ASSOCIATE, I.R.E., AND N. SMITH†, NONMEMBER, I.R.E.

DATA on the ordinary-wave critical frequencies and virtual heights of the ionospheric layers during April are given in Fig. 1. Fig. 2 gives the monthly average values of the maximum usable

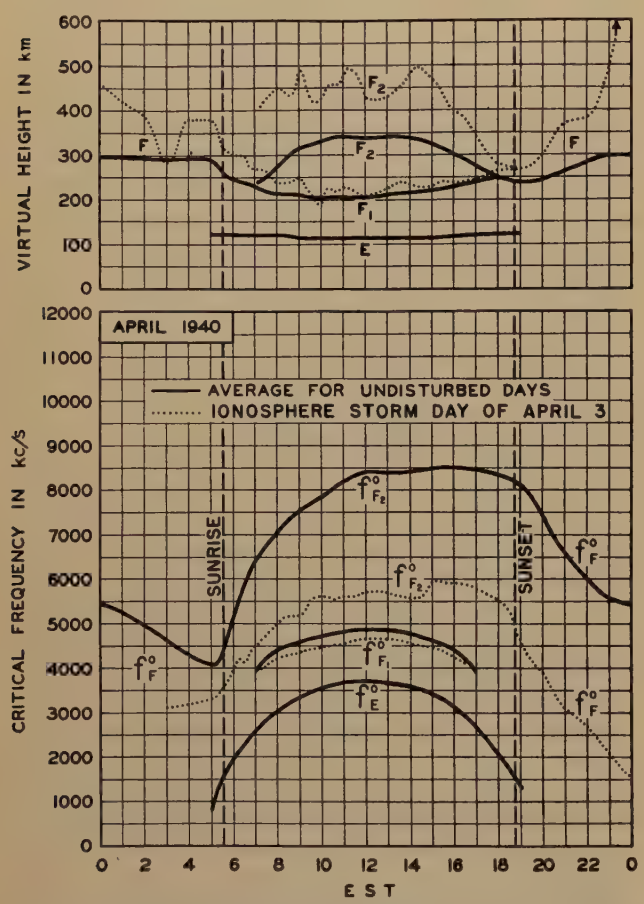


Fig. 1—Virtual heights and critical frequencies of the ionospheric layers, April, 1940.

frequencies for undisturbed days, for radio transmission by way of the regular layers. The maximum usable frequencies were determined by the F layer at night and by the E, F_1, and F_2 layers during the day.

Fig. 3 gives the distribution of hourly values of F and F_2 critical-frequency data about the undisturbed aver-

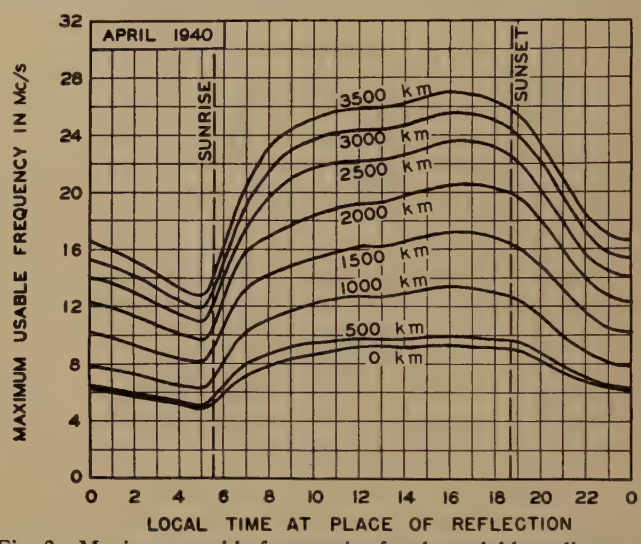


Fig. 2—Maximum usable frequencies for dependable radio transmission via the regular layers, average for undisturbed days for April, 1940. For information on use in practical radio transmission problems, see Letter Circular 575 obtainable from the National Bureau of Standards, Washington, D. C., on request.

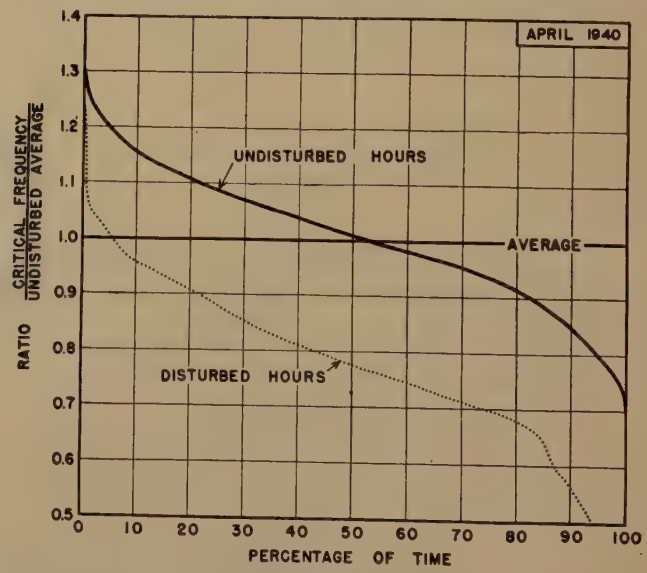


Fig. 3—Distribution of F- and F_2-layer ordinary-wave critical frequencies (and also approximately of maximum usable frequencies) about monthly average. Abscissas show percentages of time for which the ratio of the critical frequency to the undisturbed average exceeded the values given by the ordinates. The solid-line graph is for 440 undisturbed hours of observation; the dotted graph is for 211 disturbed hours of observation listed in Table I.

* Decimal classification: R113.61. Original manuscript received by the Institute, May 13, 1940. These reports have appeared monthly in the PROCEEDINGS starting in vol. 25, September, 1937. See also vol. 25, pp. 823–840; July, 1937. Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

† National Bureau of Standards, Washington, D. C.

age for the month. The variations from the average were greater than usual. Fig. 4 gives the expected values of the maximum usable frequencies for radio transmission by way of the regular layers, average for undisturbed days, for July, 1940.

Ionospheric storms and sudden ionospheric disturbances are listed in Tables I and II, respectively. Strong vertical-incidence sporadic-E reflections were observed above 6 megacycles only one hour during the month, and above 4.5 megacycles only six hours.

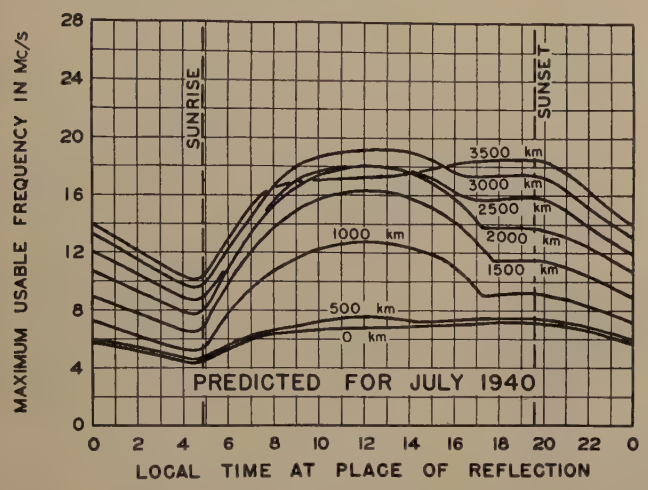


Fig. 4—Predicted maximum usable frequencies for dependable radio transmission via the regular layers, average for undisturbed days, for July, 1940. The values shown will be considerably exceeded during irregular periods by reflections from clouds of sporadic-E layer. For information on use in practical radio transmission problems, see Letter Circular 575 obtainable from the National Bureau of Standards, Washington, D. C., on request.

TABLE I

IONOSPHERIC STORMS (APPROXIMATELY IN ORDER OF SEVERITY)

Day and hour E.S.T.	h_F before sunrise (km)	Minimum f^0_F before sunrise (kc)	Noon $f^0_{F_2}$ (kc)	Magnetic character[1] 00–12 G.M.T.	Magnetic character[1] 12–24 G.M.T.	Ionospheric character[2]
April						
25 (after 1400)	—	—	—	1.4	1.4	1.3
26	418	diffuse	4700	1.1	0.4	1.6
27 (until 1200)	350	2600	6300	0.2	0.2	0.6
2 (after 1300)	—	—	—	0.4	1.1	1.5
3	372	diffuse	5700	1.6	1.2	1.3
4	[3]	<1600	6400	0.6	0.5	1.1
5 (until 0500)	304	3300	—	0.4	0.0	0.1
1	352	diffuse	6400	1.5	1.0	1.0
2 (until 1300)	334	2600	5900	0.4	1.1	1.0
20 (after 2000)	—	—	—	0.4	0.7	0.2
21	332	2800	no data	0.8	0.5	0.5
22	330	3100	no data	0.6	0.2	0.6
23 (until 0600)	316	diffuse	—	0.0	0.0	0.3
24 (after 2200)	—	—	—	0.0	0.0	0.3
25 (until 1400)	340	3100	7700	1.4	1.4	0.6
16 (after 0900)	—	—	7600	0.6	0.2	0.2
17 (until 0500)	304	3900	—	0.3	0.0	0.2
14 (until 0500)	316	4500	—	0.5	0.2	0.1
For comparison: average for undisturbed days	292	4090	8420	0.1	0.2	0.0

[1] American magnetic character figure, based on observations of seven observatories.
[2] An estimate of the severity of the ionospheric storm at Washington on an arbitrary scale of 0 to 2, the character 2 representing the most severe disturbance.
[3] No measurement because f^0_F was less than 1600 kilocycles.

TABLE II

SUDDEN IONOSPHERIC DISTURBANCES

Day	G.M.T. Beginning	G.M.T. End	Locations of transmitters	Relative intensity at minimum[1]	Other phenomena
April					
2	2037	2052	Ohio	0.05	
15	1616	1635	Ohio, Cuba, D. C.	0.0	
16	1506	1520	Ohio, Cuba, D. C.	0.0	Ter. mag. pulse,[2] 1504 to 1513
20	1505	1540	Ohio, Cuba	0.1	
28	1753	1810	Ohio, Cuba, D. C.	0.02	

[1] Ratio of received field intensity during fade-out to average field intensity before and after, for station WLWO, 6060 kilocycles, 650 kilometers distant.
[2] As observed on Cheltenham magnetogram of United States Coast and Geodetic Survey.

Correction

Sergei A. Schelkunoff has brought to the attention of the editors an error in his paper, "A General Radiation Formula," which appeared in the October, 1939, issue of the PROCEEDINGS on pages 660 to 666. In equation 21 on page 665 the factor "4" in the denominators should be "2."

Institute News and Radio Notes

What the Institute Does for Its Members*

R. A. HEISING, PRESIDENT, 1939

I WANT to talk to you today about the Institute. I have discovered that there is a wide variety of ideas extant as to what the Institute is for. I have also discovered many widely divergent ideas as to what the Institute accomplishes. There is a large number of engineers who do not seem to be aware of the material benefits which the Institute has been instrumental in conferring upon them personally, and upon society. They do not think that the world would be any different without the Institute. I wish therefore to talk to you about what the Institute means to us.

Thirty years ago, radio was in its infancy. Radiotelegraphy was in commercial and military use, while radiotelephony, though accomplished technically, had not developed to a practical stage. Engineers and others interested in radio technical development felt the need of means of discussion and of publication. A number of small clubs or societies were formed for these purposes. The extant engineering and technical societies of the time catered to the technical fields which had had extensive development and seemed unable or unwilling to supply the needs of the handful of men who were pushing the development of a new and uncertain field. In 1912 two of these small radio organizations, feeling that their small size hindered their efforts, united and the Institute of Radio Engineers was formed.

RAYMOND A. HEISING
President, 1939

One of the best ways of estimating what the Institute is doing for its members and for society is to look over its early history and see what it has done in the past. Reasonable extrapolation can give some indication of what it can do in the future. During the early years of the life of the Institute, a considerable number of important papers were delivered at Institute meetings and published in its PROCEEDINGS. These papers covered a number of phases of radio technology and were of such basic character as to form the foundation of most of the developments of later years. It is of interest to mention a few so as to show their importance.

To begin with, a paper by J. V. L. Hogan on "Heterodyne Reception" in 1913 described in a technical fashion the system of heterodyne reception invented by his coworker Fessenden. Heterodyne reception was an important improvement in telegraphic reception, and was the forerunner of superheterodyne reception for both telegraphy and telephony. Then a paper by F. A. Kolster on "Effects of Distributed Capacity of Coils Used in Radio Telegraphic Circuits" pointed out limitations in tuned circuits that have never ceased to trouble us. The study of the important subject of radio propagation was advanced by Professor Kennelly in a paper on "The Daylight Effect in Radio Telegraphy."

In 1914 de Forest published his famous paper on "The Audion—Detector and Amplifier" which outlined his thermionic three-element vacuum tube and some of the useful circuits in which it would function. This paper on an epoch-making invention can hardly be surpassed in importance. This was followed a year later by Major E. H. Armstrong's paper entitled "Some Recent Developments in the Audion Receiver" in which he explained more about the unusual properties of the new tool and described some amazing new circuits and performances. This paper stands as one of the foundation stones of all subsequent radio developments. There followed a paper by Langmuir on "Pure Electron Discharge and Its Applications in Radio Telegraphy and Telephony." There followed further important papers on Measurements, Transmission, Apparatus and Material Constants and Characteristics, Secondary Emission, and other phenomena. Professor L. A. Hazeltine published in 1918 the first comprehensive paper on audion oscillators. He described numerous forms, explained dynamic characteristics and introduced to the radio world that indispensable measuring unit called "mutual conductance." Then there appeared van der Bijl's paper entitled "Theory and Operating Characteristics of the Thermionic Amplifier," which presented the vacuum tube as a circuit element, both in theory and in numerous practical circuits. This paper laid the foundation for quantitative engineering of tubes and circuits. There followed in the next few years a paper on Modulation by the speaker, Superheterodyne by Mr. Armstrong, and papers by T. Johnson describing many radiotelephone and telegraph sets of the vacuum-tube type presenting to the engineering world descriptions of

* Part of the opening addresses delivered before Pacific Coast Convention, San Francisco, June 27, 1939, and the Fourteenth Annual Convention, New York, N. Y., September 20, 1939.

actual radio equipment that had been developed for government war use. There were numerous other important papers, but I mention only those that happen to come to mind. The PROCEEDINGS in the first eight years of its existence contains an amazing array of papers on basic radio engineering technology, which have laid the foundation for all the radio industry of today.

One might ponder as to what the situation would have been without the Institute or PROCEEDINGS in those early days. We might ask ourselves a first question, "Would broadcasting have begun?" Probably not. A new industry can scarcely start without technical information being in the hands of a promoter. Without the PROCEEDINGS those important early papers would either not have been published, or would have been published in radically abbreviated form to conform to interests of other publishing channels. Would not the trade magazines publish them? No. Remember there were no radio trade or engineering magazines in those days. Technical magazines were in existence only for those industries which had developed to some size. They would publish only popular abstracts on radio subjects. They would not publish the more theoretical parts, very theoretical at that time though commonplace to us now. The scientific societies would not have been interested in most of them and the engineering societies might not have taken them all. Engineering societies at that time had not arrived at the stage of development which provides for groupings of papers and meetings for engineering specialists. In fact it was the unsatisfactory meeting and publishing situation of thirty years ago that led to the formation of the Institute.

Turning now from the pioneer stage we can consider the second stage, that from 1920 to the present time. During this time broadcasting stepped to the front and developed with tremendous strides. For a number of years it felt its way along using the simplest and cheapest apparatus possible, and in the course of six or eight years utilized most of the technical principles published during the pioneer stage. But its progress did not stop. It continued to advance because of new discoveries and inventions made by the increasing army of technical men employed in its various organizations.

We may now ask ourselves a second question, "Would broadcasting once begun have advanced as it did without the Institute and the PROCEEDINGS?" Again the answer is No. The advancement and development of the art also required publication and discussion for the rate of growth that occurred. During these nineteen years radio technique has advanced enormously. Accomplishments which are commonplace today seemed only a few years ago to be too much to expect. One might have wished many times for what appeared impossible, and only the most optimistic could have believed there would have been made the advances that actually occurred. These accomplishments however could not have attained their present status without the interchange of technical information between the various engineers. In this interchange of information our Institute and its PROCEEDINGS have played a most prominent part. Throughout the pages of the PROCEEDINGS is spread a record of these advances step by step as they were made. Their publication enabled all engineers to profit by the work of the various experimenters. The radio art, society, and all engaged in the radio industry owe much in their present position to the Institute and the PROCEEDINGS.

It is however easy to ask if the radio industry could not have advanced to its present position with the help of the trade and engineering journals alone, without the PROCEEDINGS. Again the answer is easily given and it is No. It is to be remembered that the radio trade and engineering journals did not exist before the radio industry, but that the PROCEEDINGS did. It is to be observed that trade and engineering journals arise only after an industry grows enough to support them. The journals never come first, as did the PROCEEDINGS. It is also to be observed that the trade and engineering journals do not publish the more highly technical articles which do not appeal to the majority of their subscribers. They publish only articles that have immediate engineering appeal or technical news value, and candidly say that there are many types of papers that do not appeal to a sufficient number of their readers to justify publishing them. However, such papers often are small steps which each in itself does not seem important, but when added together provide a chain of developments which later become of great value. Such papers appear in the PROCEEDINGS and are thus available to all engineers when their importance is recognized. The Institute and the PROCEEDINGS thereby have provided for the radio art an avenue of publication that would not have existed if the trade and engineering journals had been depended upon alone. It is therefore possible to say that the rate of progress which radio has experienced in the last nineteen years would not have occurred without an avenue of publication like that of the PROCEEDINGS.

As to the future, the value of the Institute to each of us can be ascertained approximately by a little logical extrapolation. One might consider first what would happen without any avenues of publication. That is, one can assume as an extreme case that all publication cease. Then our dissemination of knowledge ceases. Progress would be very small.

Progress would be limited to the rate of progress of the best technical organization alone. Many engineers would have to acquire information about advances by inspection of their competitor's apparatus. The best technical organization would however make much slower progress than under present conditions where many ideas and suggestions come from outside. Lack of avenues of dissemination of technical information

would reduce the rate of progress so much that according to present standards, the art would be practically standing still.

If one considers a milder case and assumes only the absence of the Institute and kindred organizations, there would still be the trade and engineering journals to disseminate information. Under their publishing policies, only articles appealing to large numbers of their readers would be published and a radical difference in progress would be observed. The more theoretical papers would not be welcome. The young developing ideas would be ignored unless everyone was thinking of them. Any policy that limits publication to material of interest to the majority of engineers will effectively stifle most new ideas. Few ideas develop fully in one mind. Stimulation and suggestion come to one mind when communicating with another, so that for new ideas in the formative stage the restricted and controlled publication policy is deadly.

The paper and publishing policy of the Institute however does not come under such a classification. The Institute follows a policy which enables all with new ideas to present them whether they seem of utility or not. It has a policy which spreads ideas throughout the world hoping that somewhere they may fall upon fertile ground. It has a policy which is necessary for the full development of any subject that may be useful to the art and society.

To recapitulate; first, it is to be observed that the Institute has been instrumental in disseminating scientific and technical information that forms the foundation of the radio enterprises of today. Second, it has been indispensable in providing a world wide avenue of discussion and publication that has assisted the rapid development of radio in the last nineteen years. Third, it continues and will continue to handle publications upon matters of current interest together with articles upon new and untried ideas without censorship so that the art may develop technically to the fullest extent.

With this picture of what the Institute does, it now becomes possible to say something about what the Institute means to us members. Not only can this be expressed in a lofty idealistic fashion, but it can be expressed in simple everyday materialistic fashion. It can be expressed so that even the least philosophic mind can comprehend the major facts. We may not only say that the Institute has been instrumental in providing a new and useful service to society through radio, but we may say it has been instrumental in providing jobs for most of us. We may not only say that the Institute has taken an important part in the improvement of radio services for the people of the nation, but we may say that it has likewise been an important factor in improving the lot of those of us associated with radio enterprises. We may not only say that the Institute will continue to take an essential part in the future development of radio for mankind, but we can also say that it will continue to play a vital part in insuring the economic well-being of those in radio. Briefly the Institute is a useful and valuable institution to society, and is also an institution that returns to the radio engineer dividends of a material kind.

In presenting this picture of what the Institute means to us, I have a definite object in mind. I would like to see all engineers and scientists engaged in radio work as members of the Institute. I would like to have you keep this picture of the Institute in mind so as to interest new engineers who enter radio work. I would like to see those who are eligible to full membership to become full Members if they are not so at present. In short, I want to encourage fuller support of the Institute by members of the radio engineering profession.

FOURTH PACIFIC COAST CONVENTION
Los Angeles, California—August 28–30

For the fourth consecutive year, our Pacific Coast Sections have joined together in arranging for a convention. The previous meetings having been held in Portland, San Francisco, and Seattle, it is now the pleasure of our Los Angeles group to play host. Headquarters will be in the Ambassador Hotel.

As in the past, this Convention will be held coincidentally with the Pacific Coast Convention of the American Institute of Electrical Engineers which is scheduled for August 27–30. The facilities and location are such as to allow participation in both meetings. Material of interest to radio engineers included in their program is scheduled for Tuesday afternoon, August 27, the day before our Convention opens. Institute members are invited to attend this and other meetings of the American Institute of Electrical Engineers.

There will be two seminars or informal discussion meetings at our Convention. The first of these will be held on Wednesday afternoon, August 28, after the technical papers session and will be devoted to high-fidelity audio-frequency systems. The second will be on the next afternoon and will consider developments in frequency-modulated-wave systems.

On Friday afternoon, August 30, four inspection trips have been arranged to the following places:

1. California Institute of Technology (200-inch mirror)
2. Studios of the National Broadcasting Company
3. KNX transmitter
4. Huntington Library

Summaries of all but three of the papers are given immediately following the program and are arranged alphabetically by the names of the authors.

PROGRAM

Wednesday, August 28

MORNING SESSION

1. "Causes of Frequency Variations in Klystron Oscillators," by E. L. Ginzton, W. W. Hansen, R. H. Varian, and J. R. Woodyard, Stanford University, Stanford University, Calif.
2. "Ultrahigh-Frequency Tubes," by A. V. Haeff, RCA Manufacturing Company, Inc., Harrison, N. J.
3. "Rectilinear Electron Flow in Beams," by J. R. Pierce, Bell Telephone Laboratories, Inc., New York, N. Y.
4. "Propagation of Electromagnetic Waves Inside a Cylindrical Metal Tube and Along Other Types of Guides," by C. P. Hsu, California Institute of Technology, Pasadena, Calif.

AFTERNOON SESSION

5. "Measurements of Noise and Vibration," by H. H. Scott, General Radio Company, Cambridge, Mass.
6. "Distortion Measurements by Fundamental-Suppression Methods," by W. K. Hewlett and David Packard, Hewlett-Packard Company, Palo Alto, Calif.
7. "A Resistance-Capacitance Audio-Frequency Oscillator," by G. A. Brettell, California Institute of Technology, Pasadena, Calif.
8. "Generation of Square-Wave Voltages at High Frequencies," by W. H. Fenn, University of California, Berkeley, Calif.
9. "Design and Test of Sound Equipment by the Intermodulation Method," by J. K. Hilliard, Metro-Goldwyn-Mayer Pictures, Culver City, Calif.
10. "Building the World's Farthest-North Commercial Broadcast Station," by J. W. Wallace, Puget Sound Broadcasting Company, Inc., Seattle, Wash.

Thursday, August 29

MORNING SESSION

11. "Frequency Modulation," by E. H. Armstrong, Columbia University, New York, N. Y. (Address before joint meeting with A.I.E.E.)
12. "Frequency-Modulated-Wave Broadcast Transmitters," by W. R. David, Radio and Television Department, General Electric Company, Schenectady, N. Y.
13. "Performance Characteristics of Frequency Modulation in Ultrahigh-Frequency Sound Broadcasting," by R. F. Guy, National Broadcasting Company, New York, N. Y.

AFTERNOON SESSION

14. "Frequency-Modulation Tests and Experience," by M. V. Kiebert, Jr., Jansky and Bailey, Washington, D. C.
15. "Frequency Modulation Versus Phase Modulation," by C. J. Breitwieser, Lee de Forest Laboratories, Los Angeles, Calif.
16. "Loktal-Tube Design and Manufacture," by R. M. Wise, Hygrade Sylvania Corporation, Emporium, Pa.
17. "Vacuum Tubes in Chemical Research," by C. J. Penther and D. J. Pompeo, Shell Development Company, Emeryville, Calif.
18. "A Proposal for Reduction of Polarization Errors in Loop Direction Finders," by F. E. Terman, Stanford University, Stanford University, Calif., and J. M. Pettit, University of California, Berkeley, Calif.
19. "Radio Direction Finding for Meteorological Balloons at 1.67 Meters," by L. C. Yuan and S. S. Mackeown, California Institute of Technology, Pasadena, Calif.

Friday, August 30

MORNING SESSION

20. "Some Notes on Linear and Grid-Modulated Radio-Frequency Amplifiers," by F. E. Terman, Stanford University, Stanford University, Calif., and R. R. Buss, Heintz and Kaufman, Ltd., South San Francisco, Calif.
21. "A 500-Kilowatt High-Efficiency Broadcast Transmitter," by J. O. Weldon, Weldon Engineering Company, Del Rio, Texas.
22. "RCA Portable Television Pickup Equipment," by G. L. Beers, RCA Manufacturing Company, Inc., Camden, N. J.
23. "Television Receiver Characteristics," by C. F. Wolcott, Gilfillan Brothers, Inc., Los Angeles, Calif.
24. "Mutual Acoustic Impedance in Multiple-Speaker Systems," by H. S. Knowles, Jensen Radio Manufacturing Company, Chicago, Ill.
25. "Portable Television Broadcasting," by H. R. Lubcke, Don Lee Broadcasting System, Los Angeles, Calif.

SUMMARIES OF TECHNICAL PAPERS

22. RCA PORTABLE TELEVISION PICKUP EQUIPMENT

G. L. BEERS
(RCA Manufacturing Company, Inc., Camden, N. J.)

In 1938, a mobile television pickup equipment was developed. This equipment was mounted in two units, each unit being about the size and shape of a 25-passenger bus and weighing 10 tons. This paper describes a new, lightweight portable television pickup

equipment which does not have the limitations of size, weight, and power requirements of the earlier equipment. This new equipment uses suitcase type of construction and weighs (exclusive of cable) 550, 850, and 1050 pounds for one, two, and three cameras, respectively.

A description of the general characteristics of the equipment is given together with the function of each unit. The relay transmitter has a peak output of 25 watts at any frequency from 280 to 340 megacycles.

It is possible to carry the complete pickup apparatus into any building, amusement park, theater, etc., in order to televise events which are inaccessible to pickup equipment mounted permanently in a truck.

15. FREQUENCY MODULATION VERSUS PHASE MODULATION

C. J. Breitwieser
(Lee de Forest Laboratories, Los Angeles, Calif.)

The fundamental properties of amplitude, phase, and frequency modulation are discussed and defined. The sideband constitution and the advantages of phase modulation over frequency modulation are then discussed. The optimum modulation index is shown to be $K/6$. A practical transmission and reception system is described and a new method of demodulating a phase-modulated wave is given. The distortional characteristics of the system are analyzed and optimum conditions shown. Two transmitter circuits are given, one for ordinary frequencies and one for the ultrahigh frequencies. The paper concludes with a summary of the chief advantages of phase modulation over other systems.

7. A RESISTANCE-CAPACITANCE AUDIO-FREQUENCY OSCILLATOR

G. A. Brettell
(California Institute of Technology, Pasadena, California)

A single-tube oscillator is described which utilizes resistive and capacitive elements only. A normal design leads to harmonic contents of less than $\frac{1}{4}$ per cent and a frequency stability of better than 1 part of 10,000 for a 10 per cent supply-voltage variation. The design criteria are derived and distortion and stability measurements presented for various operating conditions.

12. FREQUENCY-MODULATED-WAVE BROADCAST TRANSMITTERS

W. R. David
(General Electric Company, Schenectady, N. Y.)

This paper presents the relative merits of phase modulation and direct frequency modulation. Problems of circuit design are discussed. These problems include frequency-modulation methods, frequency stability, low noise level, low distortion, and linearity.

Detailed description of the circuit used in the General Electric transmitter is presented, together with the performance characteristics of a 1-kilowatt frequency-modulated broadcast transmitter.

Other problems of high-power transmitters, mechanical design, relay transmitters and receivers, and service area are also considered.

8. GENERATION OF SQUARE-WAVE VOLTAGES AT HIGH FREQUENCIES

W. H. Fenn
(University of California, Berkeley, Calif.)

Three methods are described for the generation of alternating voltages having a square wave shape and covering a wide range of frequencies. The first method is based on a previously developed system and uses an overloaded direct-coupled degenerative vacuum-tube amplifier. The second method uses a special pulse generator followed by a vacuum-tube trigger circuit. The third method is a combination of the first two and produces waves which are squarer than those produced by the individual systems.

Very square waves are obtained with all systems at frequencies up to 200 kilocycles per second and with loading capacitances up to 100 micromicrofarads. The applications of these waves are considered, as well as the importance of the circuits for other purposes.

1. CAUSES OF FREQUENCY VARIATIONS IN KYLSTRON OSCILLATORS

E. L. Ginzton, W. W. Hansen, R. H. Varian, and J. R. Woodyard
(Stanford University, Stanford University, Calif.)

Fundamental causes of frequency variation in Klystron oscillators will be discussed quantitatively. Variation of frequency with voltage is treated along the general lines laid down by Webster but using more-customary engineering terminology. Variation of frequency with current is due to change of resonator frequency arising from the dielectric constant of the electrons inside the resonators. The theory of this will be developed in some detail. Various representative practical cases of frequency variations due to both cases will be discussed.

13. PERFORMANCE CHARACTERISTICS OF FREQUENCY MODULATION IN ULTRA-HIGH-FREQUENCY SOUND BROADCASTING

R. F. Guy
(National Broadcasting Company, Inc., New York, N. Y.)

During the last year the National Broadcasting Company completed an investigation of the performance characteristics of frequency modulation, building for the purpose a 1-kilowatt transmitter W2XWG, four special receivers, and other equipment. The trans-

mitter and receivers were specially built for either amplitude modulation or frequency modulation with various frequency swings. Comprehensive measurements of the relative performance of these types of modulation were made at eleven scattered receiving locations. The paper will describe the equipment, the measurements, and the field observations. By a series of figures it will show the relative performance of the various types of modulation and analyzes the reasons for the differences. These differences result from the use of high-frequency pre-emphasis, the triangular noise spectrum of frequency modulation, and the deviation ratio, or index.

Considerable data will be shown on the frequency-modulation noise threshold. Measurements of fluctuation and impulse noise will be shown under a variety of conditions and data will also be presented covering the operation of frequency-modulated-wave stations on the same channel and adjacent channels. There will be a discussion of methods of calculating the advantage under various conditions of frequency modulation over amplitude modulation in the suppression of noise.

6. DISTORTION MEASUREMENTS BY FUNDAMENTAL-SUPPRESSION METHODS

W. R. Hewlett and David Packard
(Hewlett-Packard Company, Palo Alto, Calif.)

Two methods are discussed for the measurement of harmonic distortion by suppressing the fundamental.

The first method may be used to estimate closely the percentage of distortion in an amplifier and at the same time determine the type and character of the distortion. This method uses a filter for eliminating the fundamental and a cathode-ray oscilloscope for observations and measurements.

The second method makes use of a local synchronized oscillator and a resistance bridge for suppressing the fundamental. The percentage of distortion is then read on a total root-mean-square-type meter. This system has the advantage that it will cover the entire audio-frequency range even though the source of signal is remotely located.

9. THE DESIGN AND TEST OF EQUIPMENT BY THE INTERMODULATION METHOD

J. K. Hilliard
(Metro-Goldwyn-Mayer Pictures, Culver City, Calif.)

This paper discusses the fundamental difference between the single-frequency method as compared to the two-frequency method of testing electrical equipment. Comparison between the harmonic method and the intermodulation method is discussed and advantages outlined. The apparatus used to make the measurements is described and a summary of the dynamic tests of various electrical and acoustic equipment is presented.

4. PROPAGATION OF ELECTROMAGNETIC WAVES INSIDE A CYLINDRICAL METAL TUBE AND ALONG OTHER TYPES OF GUIDES

C. P. Hsu
(California Institute of Technology, Pasadena, Calif.)

The prime purpose of this paper is to base the discussion of the properties of propagation of electromagnetic waves inside a metal tube upon the theory of complex functions. The general expressions for the field components for different types of excitation systems are obtained in a rigorous manner starting from that of an electric and a magnetic dipole. The formal mathematical generalization is achieved by means of the transformation formulas of cylindrical functions and the results of the theory of integral equations. The integral equations thus obtained are expanded into series by aid of residual calculus for actual numerical calculation.

The residues at the poles of singularities give rise to different "distinct modes" of propagation and thereby a comprehensive discussion of all the important physical properties is made. At the same time, problems arising in practical applications, say for long-distance transmission for television purposes, are analyzed and some interesting conclusions obtained. The unique and rigorous analysis is made possible by the free use of the results in the theory of complex functions.

A comparison of the properties of propagation with regard especially to the attenuations and the velocities of propagation inside a hollow cylindrical metal tube guide and that of a concentric system is made.

24. MUTUAL ACOUSTIC IMPEDANCE IN MULTIPLE-SPEAKER SYSTEMS

H. S. Knowles
(Jensen Radio Manufacturing Company, Chicago, Ill.)

The efficiency and directional characteristics of multiple speakers or sound sources depend on the total acoustic impedance, including the mutual or interaction impedance between the sources, seen by each source.

By application of the principle of acoustic images the radiation and mutual impedance for a number of special boundary conditions are obtained. The relation of these factors to "space phasing" is also discussed.

25. PORTABLE TELEVISION BROADCASTING

H. R. Lubcke
(Don Lee Broadcasting System, Los Angeles, Calif.)

Portable television pickups form an important part of the program service of the Don Lee television station W6XAO in Los Angeles. From two to four portable pickups are made per week, each of several hours duration.

An important step in our portable technique is the

"r-f test;" a determination of the propagation conditions from the portable transmitter W6XDU, operating on 324 megacycles, to the relay-link receiver housed at W6XAO. This is made with a simplified setup.

Thirty-nine portable pickups to date have emphasized the desirability of line-of-sight propagation and maximum obtainable antenna heights. Feeder length is immaterial in this regard. An exasperating idiosyncrasy was noted in a lake pickup; horizontal polarization being used. A "pitchfork" antenna has proved most satisfactory. A portable 10-kilowatt 60-cycle prime-mover power unit is used where required. Diathermy interference has been experienced on weak signal pickups.

Permanent antenna and lighting installations are made where repeat pickups are made, such as at baseball parks, boxing, and wrestling areas. The new location of W6XAO, atop 1700-feet Mt. Lee, Hollywood, will expedite pickup work by providing an elevated relay receiver location.

17. VACUUM TUBES IN CHEMICAL RESEARCH

C. J. Penther and D. J. Pompeo
(Shell Development Company, Emeryville, Calif.)

This paper deals with the application of inexpensive radio-receiving-type vacuum tubes to low-drain voltmeters, engine-pressure indicators, apparatus for measuring dielectric constant, timing devices, friction-measuring equipment, and valve controllers. In several of these applications the tubes are used under conditions quite different from those for which they were originally designed.

3. RECTILINEAR ELECTRON FLOW IN BEAMS

J. R. Pierce
(Bell Telephone Laboratories, Inc., New York, N. Y.)

It has been found possible to obtain rectilinear electron flow according to space-charge equations for parallel planes and concentric cylinders and spheres in the form of beams surrounded by charge-free space. This has been accomplished by finding solutions of Laplace's equation which match the space-charge equations in potential and gradient over plane, cylindrical, or conical surfaces along the lines of flow. The cathode and beam are then enclosed by electrodes in the form of equipotentials of these solutions of Laplace's equation. For plane bounding surfaces and two-dimensional flow, the appropriate solutions of Laplace's equation have been obtained analytically. For cylindrical and conical bounding surfaces and axially symmetrical flow, the solutions have been obtained by the use of an electrolytic tank representing a sector of the axially symmetrical field. Utilizing such rectilinear flow in beams, electron guns have been constructed which have desirable characteristics.

5. MEASUREMENTS OF NOISE AND VIBRATION

H. H. Scott
(General Radio Company, Cambridge, Mass.)

The recent development of the sound-level meter has produced a revolution in measuring technique in many mechanical industries. Heretofore noise was a matter of opinion and there was no definite basis for measuring it in quantitative terms. A similar situation has existed until comparatively recently in the field of vibration measurement. Many mechanical devices have been in use but they are generally characterized by a restricted frequency range. While a device of this type may provide accurate and reliable results when used within its normal limitations, there is seldom any satisfactory way of knowing that the characteristics of the vibration actually fall within these limitations. For instance, the higher-frequency components of many vibrations are entirely suppressed in any measurements made with many types of mechanical vibration-measuring equipment.

Sound-level measurements in general have become so well known that it is no longer necessary to go into any particular detail on this subject. Modern sound-level meters are accurate and reliable and conform to the American Standards Association standards. Such instruments provide noise measurements within the limitations imposed by the present state of the art and have proved invaluable in many practical applications. A more recent development, the degenerative sound analyzer, has made practical the analysis of complex sounds with frequency-modulated and unpitched components with a high degree of accuracy and convenience. Recent developments in recording equipment have further expanded the usefulness of this equipment.

New developments have extended the field of sound measurements to corresponding equipment developed mainly for vibration measurements.

In chronological order, these developments have been essentially: (1) the vibration pickup for attachment to a standard sound-level meter; (2) a control box allowing variation of the frequency characteristics of the pickup—sound-meter combination to provide acceleration, velocity, or displacement characteristics at the will of the operator; (3) development of a special instrument for vibration measurements, known as a vibration meter, and covering a range down to 2 cycles per second; (4) development of an analyzer similar to the sound analyzer, but intended for the vibration-frequency range; (5) development of a complete recording assembly, consisting of vibration meter and automatic-recording analyzer. Such a device provides maximum convenience and furnishes completely inked curves showing the analysis of practically any type of vibration on the basis of vibration acceleration, velocity, or displacement.

Vibration measurements are now in the state where noise measurements were six or eight years ago. The present equipment is very useful but there are many possibilities of improvement. These will be discussed from the viewpoint of the user.

18. A PROPOSAL FOR REDUCTION OF POLARIZATION ERRORS IN LOOP DIRECTION FINDERS

F. E. Terman and J. M. Pettit
(Stanford University, Stanford University, Calif., and University of California, Berkeley, Calif., respectively)

One of the serious limitations of the radio compass has been the "night-effect" error caused by the horizontally polarized component of the sky wave which is picked up by the horizontal elements of the loop. The Adcock antenna overcomes this limitation but in proportion to size has low pickup to vertically polarized waves and so is not suitable for most applications.

The remedy proposed in this paper is to employ the conventional multiturn loop, with all its undesired pickup of the horizontal component, and then by means of additional horizontal pickup from an auxiliary antenna to neutralize the unwanted component in the output circuit of the main loop.

The requirements of the system are that the auxiliary antenna provide a voltage which can be coupled into the loop output circuit through a simple network, and which will perform properly for the desired range of wavelength, signal azimuth, angle of incidence of the sky wave, etc. The analysis shows that when the earth has a high reflection coefficient a horizontal dipole antenna, mounted on the main loop (and rotating with it) and suitably coupled, is capable of providing complete or nearly complete neutralization of the horizontal pickup, with no tuning required other than an initial adjustment.

20. SOME NOTES ON LINEAR AND GRID-MODULATED RADIO-FREQUENCY AMPLIFIERS

F. E. Terman and R. R. Buss
(Stanford University, Stanford University, Calif., and Heintz and Kaufman, Ltd., South San Francisco, Calif.)

By a system of balanced feedback, the performance of linear and grid-modulated radio-frequency amplifiers can be made to approach perfection without changing the degree of modulation, reducing the gain, or otherwise affecting the performance of the amplifier. This improvement in performance is obtained by balancing a sample of the modulation obtained from the output against a sample of the modulation obtained from the input, and modulating the resulting difference voltage (which consists of noise and distortion components) on the carrier with such polarity as to tend to cancel the original noise and distortion appearing in the ouput. This "remodulation" system of feedback unlike other systems can be applied to individual stages of linear amplification.

An important source of distortion in a grid-modulated amplifier results from the regulation of the source of radio-frequency excitation, causing the radio-frequency voltage applied to the grid of the amplifier to vary over the modulation cycle because of the variable loading of the grid when it is driven positive. It is shown that by loading the exciter with a diode biased approximately to carrier level of excitation, the variations in the radio-frequency voltage applied to the grid of the amplifier are greatly reduced. In effect, the load on the exciter is shifted from the diode to the grid circuit of the grid-modulated amplifier during the modulation peaks and the load seen by the exciter remains substantially constant. This arrangement makes it permissible to operate a grid-modulated amplifier in the positive-grid region without objectionable distortion, using an exciting source having only just enough power capacity to supply the driving power required at the peak of the modulation cycle.

10. BUILDING THE WORLD'S FARTHEST-NORTH BROADCAST STATION

J. W. Wallace
(Puget Sound Broadcasting Company, Inc., Seattle, Wash.)

Radio plays an important rôle in Alaska where wire facilities are rare. This northern empire has few broadcast stations. The newest, KFAR, at Fairbanks in the center of Alaska, is unique in its field. Where concrete is more valuable than gold ore and temperatures go to 50 and 60 degrees below zero, good construction is a problem.

The station was completed on schedule thousands of miles from radio supply stores. Power and telephone cable lines were installed, a 300-foot vertical antenna erected, and dual diversity reception used for international broadcast pickup. Miles of flat "peat" land were available for the rhombic antenna and ground system.

The service range seems only limited to the absolute sensitivity of the receiver. Consistent listening at three and four hundred miles daytime and a thousand miles nighttime seems remarkable for 1000 watts on 610 kilocycles. Such broadcasting has proved invaluable in serving the growing territory of Alaska.

21. A 500-KILOWATT HIGH-EFFICIENCY BROADCAST TRANSMITTER

J. O. Weldon
(Weldon Engineering Company, Del Rio, Texas)

A description is presented of a 500-kilowatt broadcast transmitter which has been in operation in Mexico for more than a year. It represents the first application of the Doherty high-efficiency circuit in a transmitter of over 100 kilowatts and the first commercial use of a recently developed 250-kilowatt transmitting vacuum tube. A 50-kilowatt, grid-bias-modulated driver stage

is used. A description is given of a switching system whereby either of two 250-kilowatt amplifiers may be operated separately or the two may be operated in parallel for a carrier output slightly greater than 500 kilowatts.

16. LOCKTAL-TUBE DESIGN AND MANUFACTURE

R. M. Wise
(Hygrade Sylvania Corporation, Emporium, Pa.)

This paper presents a review of features embodied in standard glass-tube press design as a result of years of experience with this design. A description of changes in stem introduced by shortening of flare to reduce over-all length of "GT" types is given and also a review of other types of headers or stems used commercially in radio receiving tube design. A discussion of glass-header design which utilizes solid pins suitable in strength for direct insertion in socket contacts and for connection to the tube element either directly or by welding of "jumper" wire or other form of connector is given.

A review of metals and alloys suitable for pins where glass-metal seals are required is given. Expansion curves and other data on a new alloy usable with the commonly available types of soft glass are presented. Superior features of the new alloy are described.

23. TELEVISION RECEIVER CHARACTERISTICS

C. F. Wolcott
(Gilfillan Brothers, Inc., Los Angeles, Calif.)

This paper presents some of the more important requirements of a television receiver having good resolution, how these requirements are met in design, and an evaluation of practical results achieved in a particular model. The requirements for a wide-band radio-frequency input circuit are given, with formulas for design, and curves showing results obtained. A simple oscillator of adequate stability is discussed. The design of intermediate-frequency band-pass networks with traps at adjacent sound frequencies is presented together with performance curves and photographs of practical production units. The response characteristics and design of video-frequency amplifiers are considered and performance shown. Stripping and the derivation of synchronizing pulses from the video information are illustrated.

19. RADIO DIRECTION FINDING FOR METEOROLOGICAL BALLOONS AT 1.67 METERS

L. C. Yuan and S. S. Mackeown
(California Institute of Technology, Pasadena, Calif.)

Different antenna systems were tested for both horizontal and vertical directivity on this wavelength at distances of from 7 to 30 miles. The antennas used in these experiments included parabolic, V, double V, Adcock, etc.

Using an Adcock antenna the azimuth of the incoming electromagnetic wave was determined within one-half degree accuracy. With a slight modification of the receiving elements to form a horizontal-H antenna, the vertical angle of the incoming wave was also obtained with the same degree of accuracy. One type antenna could be converted into the other type by mechanical means within a few seconds and thus both vertical and horizontal angles could be measured with the same antenna setup.

With the antenna one and a half wavelengths above the ground and with the ground surface homogeneous in the immediate vicinity of the receiving antenna, the horizontal and vertical direction of the incoming electromagnetic wave coincided with that of the transmitter emitting the wave, within the same accuracy of one-half degree. No tests were made at a vertical angle greater than $7\frac{1}{2}$ degrees.

Deviations from the true directions at different locations and at different times were observed. These deviations were primarily caused by irregularities and lack of uniformity in the ground near the receiver.

The receiver used for this experiment is a superheterodyne specially designed for this purpose using a resistance-coupled intermediate-frequency amplifier. It is very stable in operation and has ample sensitivity.

Membership

The following indicated admissions to membership have been approved by the Admissions Committee. Objections to any of these should reach the Institute office by not later than July 31, 1940.

Admission to Associate (A), Junior (J), and Student (S)

Albrecht, J. F., (S) 1310 Madison St., Oakland, Calif.
Allen, H. S., Jr., (S) 1720 Pacific Ave., San Francisco, Calif.
Anderson, R. G., (S) 956 University Ave., Boulder, Colo.
Anner, G. E., (S) 1988½ N. High St., Columbus, Ohio
Atherton, J. B., (S) 130 E. Lane Ave., Columbus, Ohio
Atwell, R. G., (A) 303 E. Lewis St., Fort Wayne, Ind.
Baldwin, M. W., Jr., (A) Bell Telephone Labs., Inc., 463 West St., New York, N. Y.
Barnes, P. C., (A) Radio Station WFAA-WBAP, Grapevine, Tex.
Becker, H. W., (A) 441 N. Lake Shore Dr., Chicago, Ill.
Bertolet, E. C., (A) 39 W. 94th St., New York, N. Y.
Bordeaux, C. A., (S) 413 W. Vine St., Milwaukee, Wis.
Bowser, A. P., (S) 358 Pleasant St., Brockton, Mass.
Bracic, M. M., (A) 930 Lee Ave., Farrell, Pa.
Breiter, W. J., (A) Church Rd., Bensenville, Ill.
Brociner, V., (A) Philharmonic Radio Co., 21 W. 45th St., New York, N. Y.
Budy, J. J., (S) 944 N. Marshall St., Milwaukee, Wis.
Cocci, G., (A) Via Gozzi 8, Milan, Italy
Cole, A. D., (S) 3126 Fuhrman Ave., Seattle, Wash.
Coleman, A., (A) 677 Gerard Ave., Long Branch, N. J.
Collins, J. R., (A) Radio Station WFAA, Dallas, Tex.

Cook, D. C., (S) 546 N. 79th St., Seattle, Wash.
Cornwell, R. G., (A) Radio Station WICA, Ashtabula, Ohio
Crispell, H. L., (S) 910-2nd Ave., Dodge City, Kan.
Cronk, E. R., (J) 6217 Woodlawn Ave., Chicago, Ill.
Darst, W. H., Jr., (S) 303 Forest Rd., Raleigh, N. C.
David, J. R., (S) 1000-12th St., Boulder, Colo.
Deeley, A. R., (A) 32 Swiss Ave., Chelmsford, Essex, England
Edgar, L. C., (S) 1120 N. Milwaukee St., Milwaukee, Wis.
Fragola, C. F., (S) 557 Metropolitan Ave., Brooklyn, N. Y.
Freund, W. H., (A) 350 Passaic St., Hackensack, N. J.
Gillean, I., (S) 604 Clarke Ave., Westmount, Que., Canada
Gilmour, R. R., (A) Bruntsfield, Main Rd., Muizenberg, Cape Town, South Africa.
Godbey, J. J., (S) 3324 Purdue, Dallas, Tex.
Gray, M. C., (A) Bell Telephone Labs., Inc., 463 West St., New York, N. Y.
Gray, T. S., (A) Massachusetts Institute of Technology, Cambridge, Mass.
Gronner, A., (S) c/o Pension Schurer, 4 Dufourstr., Zurich, Switzerland
Hague, H. J., Jr., (S) 831 Oak Hill Ave., S.W., Atlanta, Ga.
Hamlin, E. W., (A) University of Texas, Department of Elec. Eng., Austin, Tex.
Hartman, C. E., (S) 1083-14th St., Boulder, Colo.
Harvey, H. C., (A) 1927 Wisconsin Ave., Beloit, Wis.
Hayes, W. D., (S) 429 Perkins St., Oakland, Calif.
Helm, R., (S) Kappa Sigma Fraternity, Stanford University, Calif.
Henson, C. E., (A) 3945 Staebler Ave., Louisville, Ky.
Herman, O. R., (A) 1421 Arch St., Philadelphia, Pa.
Jones, W. J., (S) 106 W. 131st St., New York, N. Y.
Kendig, C. A., (A) 1640 Robinwood Ave., Lakewood, Ohio
Kraus, C. R., (A) 1835 Arch St., Philadelphia, Pa.
Kuhn, H. G., (A) 342 Young St., Tonawanda, N. Y.
Lehr, O. A., (A) 701 N. Gernhart Ave., Mishawaka, Ind.
Mann, D. O., (S) 2302 Dwight Way, Berkeley, Calif.
Masters, R. W., (S) 4250 Otterbein Ave., Indianapolis, Ind.
Mavy, E., (S) 1529 Webster St., Oakland, Calif.
McGregor, R. B., (A) 3945 Staebler Ave., Louisville, Ky.
Mead, S. P., (A) Bell Telephone Labs., Inc., 463 West St., New York, N. Y.
Mesa, J. O., (A) Stewart Warner Co., 1826 Diversey Pkwy., Chicago, Ill.
Messmer, G. R., (S) 1100 S. University Blvd., Denver, Colo.
Mitchell, F. T., Jr., (S) 4500 Dexter St., N. W., Washington, D. C.
Morrison, H. F., (A) 331 Center St., Ashtabula, Ohio
Newman, H. C., (A) State Police Barracks, Radio Division, Framingham, Mass.
Pease, R. M., (A) 233-33rd St., Newport News, Va.
Piecko, P. T., (A) 3808 W. Fullerton Ave., Chicago, Ill.
Ragazzini, L. J., (S) 515 W. 122nd St., New York, N. Y.
Reeves, J. J., (A) 53 Hamilton Ave., St. George, S.I., N. Y.
Ross, A. H., (S) 421 W. Johnson St., Germantown, Philadelphia, Pa.
Savage, J. W., (S) 477 Marshall Ave., San Jose, Calif.
Schafer, C. R., (A) 909 W. Broadway, Minneapolis, Minn.
Shelvock, A. J., (A) 88-48-199th St., Hollis, L. I., N. Y.
Sherman, H., (S) 1560 Amsterdam Ave., New York, N. Y.
Shulman, J. M., (S) 2753 Hampshire Rd., Cleveland Heights, Ohio
Smith, J. R., Jr., (S) Box 3501, Raleigh, N. C.
Smith, L. C., Jr., (A) 2018 Sul Ross Ave., Houston, Tex.
Stimson, F. F., (A) 2809-40th Ave. W., Seattle, Wash.
Stone, R. P., (S) 1101 Elmwood Ave., Columbus, Ohio
Szabo, B., (A) Dohany u 30, Budapest, Hungary
Taffet, M. S., (S) 3464 Wilson Ave., Bronx, N. Y.
Toy, T. G., (A) 6856 S. Halsted St., Chicago, Ill.
Vann, I. M., Jr., (S) Box 5482 State College Station, Raleigh, N. C.
Voznak, E., (A) 826 S. Wabash Ave., Chicago, Ill.
Williams, P. B., (A) 1515 W. Monroe St., Chicago, Ill.
Woonton, G. A., (A) 714½ Maitland St., London, Ont., Canada
Wyckoff, C. T., (A) 317 La Salle, Royal Oak, Mich.
Zygmunt, H. J., (A) 201 Talbot Ave., Braddock, Pa.

Books

The "Radio" Handbook.

Published by *Radio, Ltd.*, 1300 Kenwood Rd., Santa Barbara, Calif. 640 pages+18-page index. 6¾×9¾ inches. Price $1.50.

This handbook of nearly 550 pages of text (640 pages including appendix) presents broad cross sections of theory and practice of radio communication directed primarily to radio amateurs and those interested in becoming amateurs. It is of interest, however, to all those in the radio field interested in keeping up to date in amateur practice.

The first chapter covers an introduction to amateur radio, for those interested in becoming amateurs; how to obtain an amateur license, how to learn the code, and so on.

In simple language, the second chapter covers the fundamentals of electricity and illustrates calculations of circuit elements, singly and in combination.

With the present importance of vacuum tubes in radio, considerable effort is given to presenting the theory of tubes, emitters, conduction, electrons, and control.

Three chapters are devoted to receiver theory, receiving-tube characteristics, and receiver construction. All fundamental component circuits are discussed, from the simplest detectors on through to automatic volume control, noise-limiter, and noise-suppressor circuits. The constructional material is excellently presented, complete with detailed photographs, wiring diagrams and part lists. Starting with a very simple "two-tuber," several receivers ranging up to advanced superheterodynes are covered. Other articles cover a long-wave plane or boat receiver, an ultrahigh-frequency superheterodyne, and several models of high-frequency converters.

Transmitter theory, practice, and construction are covered in nine chapters. Beginning with simple component circuits such as tube and crystal oscillators, and the various classes of amplifiers, the transmitter theory is developed to cover modulated waves. Many forms of component modulator circuits are described with emphasis on the power relationships in carrier and modulator stages. Component speech circuits and elements are discussed including various types of microphones and speech amplifiers from the simplest to those including automatic peak limiting and automatic modulation control. A very complete list of transmitter tubes, cross-indexed as to power capabilities, is included.

In transmitter construction, designs particularly suited to amateurs are covered. The beginner's simple low-powered transmitter may be used as the exciter of an expanded more elaborate transmitter built later. Safety precautions are given, but, while the material presented on this topic is good, it is the reviewer's opinion that it should receive much greater prominence.

The constructional material is excellently presented, with detailed photographs, wiring diagrams, and parts lists. Several transmitters, or exciters, ranging from a two-band unit of 15 watts up to a semi-band-switching unit of 100 watts are described. Power amplifiers, for use following these, are described for powers from 200 to 800 watts. Power-supply units, with data on choke and transformer design and construction, are also covered. Four or five complete transmitter assemblies are also described, for those who wish to proceed at once with the construction rather than follow the step-by-step expansion program. These range from a 250-watt continuous-wave transmitter to a 400-watt, 10- to 160-meter phone transmitter.

A separate chapter is devoted to ultrahigh-frequency communication with special attention paid to portable or mobile applications and to power supplies.

A chapter is given on antennas, with a discussion of radio wave propagation, and

indicates the reasons for the directivities for practical amateur communication. Both horizontal and vertical directivity patterns are considered, with the modifications in each caused by ground conditions. Only those directive systems which are of practical amateur interest, because of space available or height above ground, are considered. A few examples of rotatable arrays are described.

The latter chapters are devoted to Test and Measuring Equipment, (such as wavemeters, frequency standards, vacuum-tube voltmeters, modulation-test sets, and so on) Workshop Practice (covering suggestions in tools and their proper handling, for beginners), Diathermy Machines, Radio Mathematics, and the amateur Radio Laws and Regulations.

The appendix includes a quick reference index of main subjects, a very complete main index, and a miscellany of useful items, including a list of the "*Q*" signals, R-S-T signal-reporting system, international amateur call prefixes. Federal Communications Commission rules on good practice and a buyer's guide for all parts used in the model transmitters and receivers described in the text.

This latest edition of a very popular amateur handbook presents its mass of theory and practic : in a clear style well adapted to the readers for which it is mainly intended. The theoretical parts are exceptionally well written, condensing and summarizing into simple language without any serious loss of accuracy.

J. K. Clapp
General Radio Company
Cambridge, Mass.

The Victory of Television, by Philip Kerby.

Published by Harper and Brothers, 49 East 33rd St., New York, N.Y. 115 pages+3-page index and 9 pages of illustrations. Price $1.00. $5\frac{3}{4}\times 8\frac{1}{4}$ inches.

The jacket on this book says the author '. . . has been hard at work for National Broadcasting Company keeping the public informed of the hourly advances in television.'

That the public has kept up an insistent demand for information on this subject during more than ten years is attested to by those associated with television. However, it is doubtful if this book really will satisfy this popular demand. This is unfortunate because it would be so very convenient to answer the many requests from nontechnical persons, varying from high-school seniors to aged poets, for general television information, by simply referring them to a comprehensive book.

"The Victory of Television" views American television, as it was in 1939, apparently through the eyes of a news reporter connected with the studio production of television programs. The first two chapters touch briefly on early television inventions and very sketchily on how a television system works. The next two chapters give the reader an excellent idea of how a modern studio appears and what goes on during a dramatic production. This is the best and most interesting part of the book.

The six remaining chapters give the author's views on the future of commercial television by discussing such subjects as: Television vs. The Theatre, Sports and News Broadcasts, Public Service Programs, Who Pays?, Sponsor's Problems, Whither Television? These chapters, based on well-known and often-discussed ideas regarding the part television is going to play in our lives (some day) paint a rather highly colored picture of the future.

Two corrections:

1. The feeling of the Federal Communications Commission toward television is not entirely that mentioned in Chapter IX. It is more far-reaching.

2. For several years the British broadcast clear, sharp pictures using 405 lines, not 220 lines (p. 83).

Albert F. Murray
Haddonfield, N.J.

Der Kondensator in der Fernmeldetechnik, by Dr.-Ing. Georg Straimer.

Published by S. Hirzel, Leipzig. Paper covers. 229 pages and 267 illustrations. Price RM13.50.

This is a book on electrical condensers with especial reference to their use in communication circuits. It forms volume 6 of the communications division of a series of works issued under the general title, "Physics and Engineering Practice of the Present."

The book must be regarded as a most thorough and exhaustive treatise on the subject of its title and it makes clear how manifold are the aspects of the problem of adapting what appears, at first sight, to be a simple type of circuit element to the many different practical cases where it finds a use.

The treatment is arranged under the three main headings, fundamental theory, physical data regarding different kinds of dielectrics, and examples of different types of condenser found in practice.

Beginning with the fundamental equations of the electrical field, formulas are derived for the calculation of capacitance in a number of different cases, and equations are given for the shapes of condenser plates for different laws of variation of capacitance with the angle of displacement. There follow solutions for various capacitance-resistance networks, used in alternating-current circuits. Attention is also directed to the usual mathematical treatment of charge and discharge transients.

In the second part of the book, there is presented full information regarding the dielectric strength, dielectric losses, and leakage resistance, as functions of temperature and frequency, of all sorts of dielectric substances, both those occurring naturally and fabricated insulating materials also.

The last third of the book is devoted to methods of manufacture of condensers and examples of condensers for all sorts of purposes, such as air condensers, electrolytic condensers, and condensers for the shielding of radio circuits from electrical disturbances caused by household appliances. This part of the book is copiously illustrated with cuts of commercial condensers from the catalogs of (quite naturally) German manufacturers. The bibliography at the end of the book lists no less than 217 titles, but this is to be regarded more as an indication of the volume of the existing literature than as an evidence of completeness, since it includes references to German periodicals only.

Frederick W. Grover
Union College
Schenectady, N. Y.

BBC Handbook 1940.

Published by the British Broadcasting Corporation, Broadcasting House, London, W.1, England. 112 pages+12-page appendix+3-page index. $7\frac{1}{2}$ by 5 inches. Price, 2 shillings.

The BBC Handbook is an annual publication which covers the activities of the British Broadcasting Corporation for the year preceding its publication. The basic form of the book is much the same as in the past, but it has particular interest this year because of the conditions in Europe which are being and will be met by special procedures.

The section entitled "Notes of the Year" comprises about one fourth of the material in the book, and is a general summary of the operation of the various departments in the British Broadcasting Corporation, as well as a brief description of the ground covered by programs presented during the year. There are several references to the war conditions and the changes which had to be effected by the British Broadcasting Corporation when war was declared. These comments on changes, however, are restricted primarily to generalities on the subject of technical operations, although they are somewhat more explicit in dealing with changes in the program and production divisions.

The next part of the book makes up about half of the material covered, and includes texts of speeches given by the Prime Minister, the King, and the Queen as well as several articles which tell in more detail the stories behind some of the more interesting events mentioned under Notes of the Year. Some of the subjects were From Peace to War, Au Revoir Television, Religion and Broadcasting, School Broadcasting in Time of War, The Listener Takes Part, and A War Diary. These articles are designed primarily to be of particular value and interest to persons in other countries who are also in the broadcast industry.

The Reference Section consists of a grouping of significant facts about the British Broadcasting Corporation and its operation as well as a simple, although sufficient, guide to listeners which offers several suggestions which might be of assistance in improving the quality of reception under normal operation. Included also are instructions concerning radio oper-

ation as to emergency calls and private messages in an attempt to minimize unnecessary use of message wires and radio facilities.

The illustrations which are included picture many of the personnel of the British Broadcasting Corporation as well as "action" pictures of programs in production and personalities such as the King and Queen. There are very few illustrations showing any kind of equipment and what few there are show studios and control room or mobile equipment which is of little or no military value.

On the whole, the BBC Handbook tells the story of the operation of a business subjected to the strains of suddenly changed and adverse conditions, and the part it plays in relieving the effects of these conditions.

HOWARD A. CHINN
Columbia Broadcasting System, Inc.
New York, N. Y.

Rundfunksiebschaltungen (Radio Filters), by R. Feldkeller.

Published by Verlag S. Hirzel, Leipzig, 1940. 168 pages. + 76 illustrations. Price, RM 12.00.

With "Radio Filters," the director of the Communication Institute at the Stuttgart Technical School continues the sequence of textbooks begun with "Transducer Theory" (Vierpoltheorie, 1938) and "Filter Theory" (Siebschaltungstheorie, 1939). Here the interest is further specialized to narrow-band filters operating between capacitive terminations in a frequency range so high that the parasitic capacitance across inductances must be considered a circuit element. That is, these radio filters are coupling networks between pentode stages.

After a preliminary consideration of the single-tuned-circuit, and the coupled-tuned-circuit interstage, the author attacks the problem of proportioning the several networks of a multistage amplifier for maximum gain with a prescribed distortion across the band. The Tschebyscheff approximation to flat transmission in the useful frequency range is used, the elements of the networks being determined algebraically when the permissible distortion and the terminating capacitances are given. Important refinements to the method are suggested by S. Darlington, *Journal of Mathematics and Physics*, volume XVIII, September, 1939, "Synthesis of Reactance 4-Poles."

The last chapter is a discussion of transient phenomena, following Heaviside.

The book is characterized by Feldkeller's lucid style and realistic approach to the engineering problem. Much in it is perfectly applicable to wide-band cases, but the control of the phase shift to meet simultaneous gain and delay requirements is not considered.

R. L. DIETZOLD
Bell Telephone Laboratories, Inc.
New York, N. Y.

Der Kurzwellensender (The Short-Wave Transmitter), by F. W. Behn and H. Monn.

Published by Weidmannsche Verlagsbuchhandlung, Berlin, 1939. 269 pages and 191 illustrations. $6 \times 8\frac{1}{2}$ inches. Price, RM 10.80.

This book considers the short-wave transmitter only. That is, it devotes little or no space to power supply, antenna, or monitor. An introductory chapter mentions the more common types of transmitters and basic components found in them. This is followed by a chapter on the fundamentals of vacuum tubes and one on resonant circuits. Then there are three chapters which take up vacuum-tube operation in some detail and four on frequency stability, including crystal and line-stabilized oscillators. The last third of the book deals with apparatus arrangement and construction and includes rather specific designs for eight transmitters ranging from 7 to 200 watts. In this last section there are no dimensional mechanical layouts, but the circuits are so drawn as to indicate the proper relative positions of parts. These, with numerous photographs, probably carry the building instructions as far as the average amateur set builder desires.

A 30-page table lists amateur transmitting tubes. About one third of them are American, but the modern tubes that contribute so much to the ease of short-wave construction are absent, as are some of the important American suppliers.

This is a second edition of a book by F. W. Behn. The treatment is nonmathematical, but makes much use of curves to show such relations as vacuum-tube or resonant-circuit characteristics or the dependence of frequency variation on plate voltage.

For the amateur who prefers the German language this is an excellent guide to home construction. It might also be of considerable use to the engineer who desires to become familiar with the technical German of radio engineering.

E. B. FERRELL
Bell Telephone Laboratories, Inc.
New York, N. Y.

Principles and Practice of Radio Servicing, by H. J. Hicks.

Published by the McGraw-Hill Book Company, 330 West 42nd St., New York, N. Y. 291 pages + 13-page index and 212 figures. Price, $3.00.

In accordance with its title the book treats both principles and practice. The treatment of principles occupies about one-half of the space, is well done, and can be very useful to any service man who desires a simple presentation of fundamental theory. The treatment of practical servicing is less systematic and thorough, but this is necessarily so in any book which is to have reasonable size. A chapter is devoted to public-address systems which is especially useful since few previous publications have included them. Omissions are few, perhaps the most important being intermediate-frequency-interference elimination (image interference is treated) and adequate emphasis on the ohmmeter method of circuit testing. The book is a worthy addition to the service man's library.

ARTHUR VAN DYCK
Radio Corporation of America
License Division Laboratory
New York, N. Y.

Ions, Electrons and Ionizing Radiations (Seventh Edition), by J. A. Crowther.

Published by Longmans, Green and Company, 55 Fifth Avenue, New York, N. Y. 331 pages + 6-page index and 117 figures. $5\frac{3}{4} \times 8\frac{3}{4}$ inches. Price, $4.00.

When the first edition of this excellent book was published two decades ago, it was intended, not as a compendious synopsis of the whole subject, but as a textbook from which students who had already gained knowledge of elementary physics might gather a systematic understanding of the important recent developments. The author has kept consistently to this purpose in the various revisions which have been made, including this latest seventh edition. The book, however, has necessarily undergone many changes in keeping apace with the tremendous increase in information resulting from the unusually large and growing number of researches in the fields included in the subject.

Most important among the changes in this latest edition are those having to do with the treatment of cosmic rays and of the nucleus, these sections having been rewritten and enlarged. These and other minor additions in other chapters reflect the progress of discovery during the five years which have elapsed since the sixth edition was published.

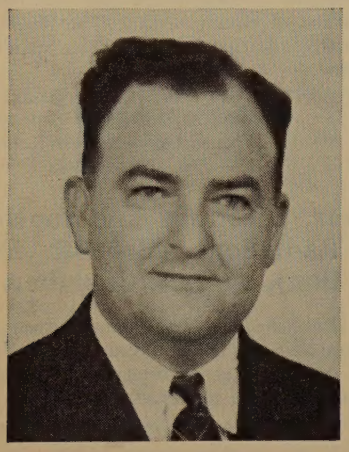
As in earlier editions, the author has avoided the use of other than rather elementary mathematics, believing that complicated mathematical derivations tend to distract the attention more than to assist in a real understanding of the physical principles involved. This does not mean, however, that the simple mathematics necessary to explain fundamental processes and principles is avoided. In fact, these definite relations are illustrated by a group of problems (with answers) at the end of the book which will be found very useful to teachers and students.

Professor Crowther's book will continue to merit the popularity it has had in the past, particularly as a second- or third-year university textbook on the newer physics and also as a reference where only the more general facts and relations are desired.

DAYTON ULREY
RCA Manufacturing Company, Inc.
Harrison, N. J.

Contributors

Pierre Baudoux was born on February 16, 1907, at Brussels, Belgium. He was graduated from the mechanical and engineering department of the University of Brussels in 1929, and from the aircraft



LEONARD J. BLACK

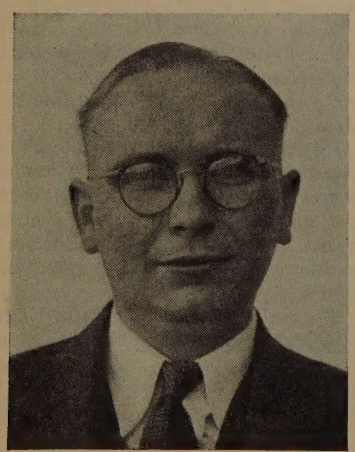
engineering department in 1930. In 1931 M. Baudoux was appointed assistant in the radio engineering department of the University and was also scientific secretary of the Belgian Institute of Radio Scientific Research. In 1935 he was promoted to Special Doctor of radio electricity and in 1937, "Agrégé." M. Baudoux is also secretary general of the Belgian Federation of Scientific Societies.

❖

Leonard J. Black (A'31) was born at Santa Clara, California, on July 29, 1905. He received the B.S. degree in electrical engineering in 1928, the M.S. degree in 1930, and the Ph.D. degree in 1935 from the University of California. From 1928 to 1929 Dr. Black was with the Pacific Telephone and Telegraph Company. He was instructor in electrical engineering at the University of California from 1931 to 1940 when he became assistant professor.

❖

Philip A. Ekstrand (S'32-A'34) was born at Loomis, Nebraska, on September 16, 1908. He received the B.S. degree from Oregon State College in 1931 and the E.E. degree from Stanford University in 1933. From 1934, to July 1939, Mr. Ekstrand



PHILIP A. E. EKSTRAND

was employed as a radio engineer at Heintz and Kaufman, Ltd., South San Francisco, and since that time he has been at the Navy Yard at Mare Island. He is a member of Tau Beta Pi, Eta Kappa Nu, Sigma Tau, Phi Kappa Phi, and an Associate Member of Sigma Xi.

❖

Lorenz Martin Klenk was born on February 19, 1907, at Kearny, N. J. In 1929 he received the B.S. degree in electrical engineering from the Newark College

LORENZ MARTIN KLENK

of Engineering. Since 1929 Mr. Klenk has been doing research and development work on short- and ultrashort-wave radio transmitters for the Bell Telephone Laboratories.

❖

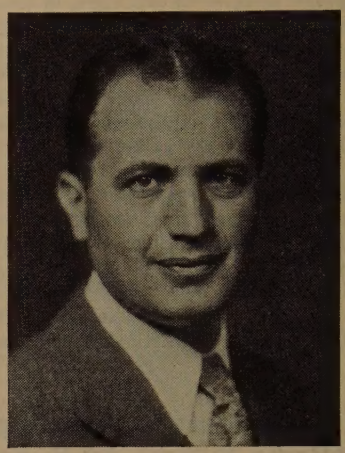
O. W. Livingston was born in Roselle, N. J., on July 11, 1905. He received the B.S. degree in electrical engineering from Rutgers University in 1927 and since that

O. W. LIVINGSTON

date he has been in the Research Laboratory and Vacuum Tube Engineering Department of the General Electric Company. He is a member of Phi Beta Kappa and an Associate Member of the American Institute of Electrical Engineers.

❖

George Rodwin (A'25-M'40) was born in 1903 in New York City. He received the A.B. degree from Columbia University in 1923 and the E.E. degree in 1925. From 1925 to 1929 he was engaged in radio research work for the Radio Corporation of America in connection with receiver, transmitter, and field-strength-measuring



GEORGE RODWIN

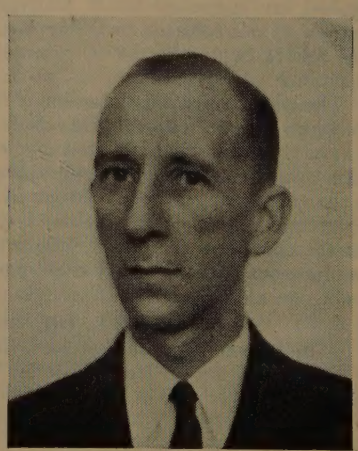
equipment. During part of 1929 and 1930 he was with the Engineering Department of the Earle Radio Corporation developing broadcast receivers. Since 1930 Mr. Rodwin has been a member of the technical staff of the Bell Telephone Laboratories where he has been carrying on research and development work on the transatlantic radio receiving equipment and general ultrashort-wave problems.

❖

Herbert J. Scott (A'19) was born at Baltimore, Maryland, on February 12, 1897. He received the B.S. degree in electrical engineering in 1927 and the E.E. degree in 1933 from the University of Washington. From 1915 to 1923 Mr. Scott was a ship and shore operator for the American Marconi Company and the Radio Corporation of America; from 1927 to 1934, engineer in radio research and development at Bell Telephone Laboratories; and since 1934, assistant professor of electrical engineering at the University of California. He is a member of Sigma Xi.

❖

For biographical sketches of T. R. Gilliland, S. S. Kirby and N. Smith see the PROCEEDINGS for January, 1940.



HERBERT J. SCOTT